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## UNDERWATER SHIP REPAIR


N. M. Madatov


271p.

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RUSSIAN




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# UNDERWATER SHIP REPAIR*

By N.M. Madatov

## Annotation

During the operation of ships, it is possible to have a breakdown of the propeller, rudder and other devices, including the bottom and hull fittings; the hull of a ship or vessel may have sustained combat or navigational damage. The problem of the present reference handbook is to instruct and to provide practical advice on how to eliminate the malfunctions of the vitally important devices and systems, how to stop leakage and to repair ruptures in the ship hull while waterborne, without resorting to the aid available at a dock or shipyard.

The individual malfunctions of the units, systems and equipment and also damages to a ship hull can be repaired more rapidly with the use of underwater ship repair and the repair will cost less than during docking since it is expensive for a ship to be drydocked. At the present time, with the dispersed basing of ships, the necessity for repair away from the main repair bases and the docking facilities is growing; therefore, a knowledge of the underwater ship repair techniques is acquiring considerable importance.

The author has described in detail the technological methods and operations of underwater ship repair, including with the utilization of underwater semiautomatic welding and cutting of metals, underwater painting and other tasks, the technique for which has been developed in recent years. A review is made of the effect of the underwater ship repair methods on the expansion of the production potentialities of the ship repair enterprises for providing the repair of the submerged section of the hull and of the important units on a ship or vessel; he also discusses the sequence of performing underwater ship repair under autonomous conditions by the personnel at the underwater ship repair stations and by the crews on board the ships. He explores the questions of the technical monitoring and safety techniques involved in underwater ship repair. The required reference materials are included in the book.



* Translation of: "Podvodnyy Remont Korabley i Sudov", Military Press (see footnote continued on next page).

Annotation (cont'd)

This reference handbook is intended for the engineering-technical workers, diving specialists, experts and crew members at the underwater ship repair stations, for the crews on ships in the navy, merchant marine and commercial fleets, instructors, military school students and students at naval training establishments. It is also of interest for a broad group of readers since it makes one familiar with a promising type of ship repair.

## PREFACE

The ability to repair the combat- and navigation-caused damages to a hull, to fix or to install new bottom and hull equipment, and to repair the propeller, rudder and other units on a ship while waterborne without the stopover of the ships at a dock or on rigid supports (shipyard) has much importance in the struggle for the viability and maintenance(of ships and of the navy as a whole) in operational readiness.

The performance of the various individual tasks by the methods of underwater ship repair permit the savings of considerable resources, since repair away from a dock while the ship is afloat is cheaper than the repair at the dock, as a result of eliminating the expenditures for the dock operation.

The continuous improvement of the technical equipment and the techniques of performing the underwater ship repair tasks requires the participants to understand the technological processes which are utilized during the underwater ship repair; the divers and ship repairmen must have the ability to make skilled use of the procedure involved.

In the periodical literature, a certain reflection has been found only by the questions of underwater welding and cutting, while the remaining questions involved in underwater ship repair have been clarified very little in the available literature.

In the present handbook, we have attempted to systematize the most significant questions in the technology of underwater ship repair. In the book, we have generalized the rich experience acquired by the underwater ship repair stations both during World War 2 and in the postwar period.



of the USSR Defense Ministry, 280 pages, Moscow 1965.

Initially in the book, we have reviewed the preparatory and then the fitting and the hull tasks. Special chapters have been devoted to underwater welding and cutting, as the most complex technological processes; the application of these processes is presented in the appropriate places in the description of the hull and metal working-repair activities. Such specific jobs as the cleaning and painting of ships underwater have been included in a separate chapter. At the end of the book, we have listed the reference data which could prove useful for practitioners concerned with underwater ship repair.

The author wishes to express gratitude to Engineers G.T. Karnaukhov and A.F. Udovenko for their valuable comments and useful advice proffered during the writing of the book, and also to Engineers S.G. Agroskin, M.M. Aleksandrov and N.A. Stoptsov for their assistance in the selection of the material.

All comments and suggestions about the book should be sent to the address: Moscow, K-160, Voyenizdat.

The Author

## INTRODUCTION

By underwater ship repair, we connote the combination of the technological processes and methods in use for repairing the damage inflicted on the submerged part of the hull and on the vitally important units (on a ship) located below the waterline, while the ship is afloat, without drydocking or hauling out; the underwater repairs are achieved with the help of the diving ship repairmen.

The individual types of underwater ship repair tasks while afloat, e.g. the removal of the propeller screws, has been accomplished in Russia for a long time. We are aware of the case of removing the propeller screws (by use of divers) on the battleship "Mariya" as early as 1915.

However, underwater ship repair received wide acceptance and recognition in our country from 1941-1945 during World War 2.

The requirement for the urgent repair of ships,with a shortage of ship-hoisting facilities, the development of the technique of the underwater welding and cutting of metals in the USSR created conditions for the performance of ship hull repairs underwater while the ship is afloat.

The first organizers of underwater ship repair were Engineer Vice-Admiral I.Ya. Stetsenko and Engineer M.A. Golovastikov. During the difficult days of the Great Patriotic War (World War 2), the foundations were laid for the technology of performing the repair tasks under water; the viability and usefulness of these procedures were proved.

Underwater ship repair can be conducted both in the basin of a ship repair enterprise as well as under autonomous conditions when the ship is away from the base. In this connection, the repair is performed at any time of year, including under winter conditions and under the ice. The possibility of moving the ship during its repair period is quite important under wartime conditions. No specially equipped shore facility is needed for the performance of the work under water. As a rule, the underwater ship repair is accomplished in combination with the work of the main shops at a ship repair enterprise.

Underwater ship repair is conducted at slight depths (up to 10-12 meters), and in distinction from the familiar methods of the repair of ships while alfoat, no special preparation of the ship is required (careening, trimming, unloading, redistribution of cargoes, etc.).

Among the disadvantages of underwater ship repair, we should include the requirement(for the performance of the ship repair tasks under water) of highly qualified staffs, combining the professions of divers and ship repairmen of various specialties (hull repairmen, fitters, welders etc.).

Owing to the insignificant introduction of mechanized work and the specific features of diving work, the labor productivity of the diving ship repairmen is still relatively low. In spite of this, underwater ship repair is economically advantageous.

Even in the first years of the development of underwater ship repair, its effectiveness and feasibility as compared with the performance of similar tasks at a dock (see table) were proved, since this eliminates the costs for the ship's stopover at the dock.

The performance of the larger tasks while afloat is also advantageous since, in addition to the savings in direct outlays for repairs, the work load at the docks is simultaneously alleviated.

In the period of W.W. 2, fairly large jobs were performed with the underwater ship repair procedure; for example, on a ship having sustained damage to the submerged part of the stern, under the supervision of Engineer M.A.Golovastikov, there was performed the cutting of the metal in the sheathing and framing with a thickness up to 56 mm. Total length of the cuts amounted to around 31 m and the work was completed in 35 diving hours at costs amounting to 7.000 rubles /See Note/. According to a rough estimate, the performance of these same tasks at a dock would have cost 35,000 rubles (K = 5). (/Note/: Here and below, the cost of repair is shown in the old scale of prices).

Table

Effectiveness of Underwater Ship Repair (based on data from one of the ship repair facilities for 1942-1945)

| Volume of repair in diving-descent hours | Cost of operations, rubles: conducted by underwater method (A) | Cost of operations, rubles: estimated if performed at dock (Б) | Savings in rubles ($B = Б - A$) | Coefficient of effectiveness ($K = \frac{Б}{A}$) |
|---|---|---|---|---|
| [illegible] | 160 | 2400 | 2240 | 15,0 |
| [illegible] | [illegible] | 3130 | 2980 | 21,0 |
| [illegible] | [illegible] | 2245 | 1445 | 2,8 |
| [illegible] | 850 | 3370 | 2520 | [illegible] |
| [illegible] | 1620 | 6000 | 4380 | 3.7 |
| [illegible] | 1720 | 4500 | 2780 | 2,6 |
| | 9555 | 32895 | 23340 | 3.4 |

Remark. A diving-descending hour is the work of a station on an object during the stay of one diving ship repairman for 1 hour under water.

In connection with the replacement of the main diesels on a tanker, under the supervision of Engr. A.A. Kas'yanov, 2 kingston valves were installed while the ship was afloat. The work was completed in 21.5 diving hours and it cost 2,170 rubles.The approximate cost of the performance of this same work at dock would have been 5,100 rubles (K = 2.3).

On a ship in the technical fleet with a displacement of around 10,000 tons, under Engr. A.F. Udovenko's guidance, there were performed the removal of the propellers, the pressing out (extrusion) of the cast-iron bushings and the removal of the shafts under water, in which one shaft was removed together with the bushing, since owing to the existing camber, it was welded to the bushing for a distance of 400 mm.

After the casting of new bronze bushings and their boring, according to the divers' information, there were also performed under water the pressing-in of the bushings, the starting of the shafts and the installation of the propellers. The weight of the loads which were raised simultaneously amounted to around 10 tons (the shafts were turned with the propellers mounted on them). The cost of the work performed by the divers amounted to 26,000 rubles based on rough estimates. The performance of this work at a dock would have cost 312,000 rubles. The examples cited testify to the sufficient maturity and effectiveness of the underwater ship repair.

The repairs of various types of ships under water is performed by the underwater ship repair stations (USRS). The staff of the USRS is composed of a director (usually an engineer-shipbuilder) (he is the producer of the work), a foreman, one or several team diving ship-repairmen and auxiliary personnel, maintaining the base support ships.

If owing to the nature of the work being accomplished the USRS does not have sufficient personnel, additional workers are placed at its disposal from the ship's crew or from the shops at the ship repair enterprise for servicing the divers from the surface.

The underwater ship repair stations are provided with the equipment, tools and other material-technical gear, including a diver's compressor or an electric pump, with heavy ventilated diving rigs— the 3-bolt or the SVV type (at least 2 sets), with an underwater telephone set, type GVTS or TSLV, with type PF-1 or VF-56 lanterns for general illumination, and the PF-2 and PFMO for local lighting; they are also equipped with the type PAS-400 autonomous welding rig. In connection with the development of underwater TV, it is recommended that the USRS also be provided with the type PTU underwater TV set.

In addition to the equipment, the USRS is also provided with a set of stripping devices, with attachments for the removal of molds, with metal working-assembling equipment, with welding tools, with a measuring instruments plant for the normal operation of the equipment available at the USRS, with cables, hoses, a welding cable, etc. In addition, in each individual case, the necessary equipment is prepared for the performance of tasks on an actual object, e.g. a box-caisson, sheets for patching, molds, and so forth.

The ship facility of the USRS is usually provided by a harbor diving boat, type VRD, or a self-propelled cutter, having in either case however a transom-type stern.

The diving boat is provided with the required navigational equipment for coastal navigation at any time of day. When necessary, the USRS is assigned floating cranes or other hoisting equipment. As a rule, the underwater ship repair stations form a component part of the ship repair enterprise and have the prerogatives of an independent shop or section. At the large ship repair enterprises, the USRS are turned over to the hull shops.

The underwater ship repair tasks are divided into 3 main groups: metal working-assembling (fitting), hull (including welding) and preparatory (auxiliary) tasks.

The metal working-assembling tasks include the repair of the underwater portion of the propeller and rudder units; repair and installation of new hull and bottom fittings; replacement of protective rings and other metal-fitting tasks.

Among the hull tasks, we include the laying out and removal of ordinates and templates of the hull's outer sheathing; the repair of holes with the installation of patches and of applied sheets; the replacement of individual units of sheathing and framing elements; removal of leakage in the riveted and welded joints, removal of dents and ridges on the outer sheathing; removal of damaged parts of the hull; repair of holes with concrete; partial repair of the hulls on wooden ships—the calking of cracks, the installation of metal sheets onto wooden sheathing; underwater scraping and painting, etc.

Among the preparatory (auxiliary) tasks, we include: the setting up of scaffolds and caissons; the slinging of the units and parts which are being disassembled; underwater inspections of the various units and the hull sheathing; measuring the clearances in the deadwood and bracket bushings; the determination of the technical condition of the hull sheathing with a test drilling, etc.

The specific percentage of the underwater tasks varies in dependence on the conditions of ships' operation, experience gained by the staff in the USRS, and on the sophistication of the technology. During W.W. 2, when the various types of ships sustained damage from enemy action, the hull type of repairs predominated.

In the postwar period, with the growth of the technology and capabilities of underwater ship repair and also with the change in the nature of the damages, more metal working-assembling and auxiliary tasks were performed. It is tentatively considered that the metal fitting-assembling tasks comprise 45-50%, the hull tasks including the underwater welding and cutting, comprise 20-25%, while the auxiliary tasks constitute 25-30%.

In the light of the present-day requirements in respect to the mobility and operational efficiency of performing the tasks, the underwater ship repair has a broad prospect for further development. At the present time, an ever-increasing significance is being acquired by the planned nature of the preparation of the production of ship repair by stages: in the period of planning and construction of a ship, of preparation of the performance of activities in the forthcoming year, in the current preparation of a ship-repair enterprise for the repair of the various types of ships.

Usually the USRS is utilized at the last stage, i.e. in the refinement of the volume of the repair tasks, for the performance of the emergency and other operations. However, as early as in the period of planning the ships, it is feasible to examine from a design standpoint the possibility of the performance of the repair to the submerged part of the hull and of the vital parts of the ship located beneath the effective waterline, utilizing the means of underwater ship repair.

The potentialities and the practice of underwater ship repair permit us to conduct the repair tasks, especially on the ships and vessels of series construction, according to standardized technological processes with a preliminary determination of the technical-economic indexes. The employment, in underwater ship repair, of the methods of the modern organization and preparation of production will reduce the unproductive outlays and the losses and will raise its effectiveness.

The use of the underwater ship repair procedures and the USRS resources at a ship-repair enterprise will curtail the docking periods of the ships and vessels. The development has indicated that in the current repair of a ship, owing to the performance of the dock-type disassembly tasks by the USRS personnel, the sojourn of a ship at dock is reduced by 25-30%.

The underwater ship repair is an original reserve of ship-repair production; its utilization will permit us to perform better and more quickly the tasks stipulated by the 22nd Congress of the CPSU (Communist Party of the Soviet Union) for the industry of our country in improving the technology of all branches and forms of production, the boosting of labor output and also in keeping the ships and vessels in operational readiness.

## CHAPTER 1

## PREPARATORY TASKS INVOLVED IN UNDERWATER SHIP REPAIR

We consider as preparatory all the auxiliary tasks, which are accomplished in the routine of preparing for the repair of the submerged part of the hull and the units of a ship which is afloat. They do not have independent significance or manifested specialization, and should be performed by all diving-ship repairmen.

Among the preparatory tasks, we include: the installation of slings and other devices for the performance of the tasks under water; the slinging of the units and parts which are being disassembled and assembled; the use of patches and of box-caissons; a diving inspection of the submerged part of the ship's hull, and so forth.

Section 1. Devices for the Underwater Performance of Tasks

**Slings.** For providing the diver with a working place during the underwater ship repair operations, use is made of the wooden and metal slings, which are paid out over the side from the deck, and are pressed against the ship hull by the under-keel (stretching) slings with the aid of pulleys, winches or other hoisting equipment.

The wooden scaffolds are usually of several types. A simple diver's scaffold is ordinarly made directly on board ship. It consists of a shield (platform) built of boards with small timbers, to which ballast is fastened on cable suspensions connected with the sliding span.

In case of the simultaneous work of 2 divers or the performance of a large volume of work, the scaffold is made with large dimensions (Fig.1). Such a scaffold is employed for inspections, measurements, removal of hull plates, for cleaning, and so forth.

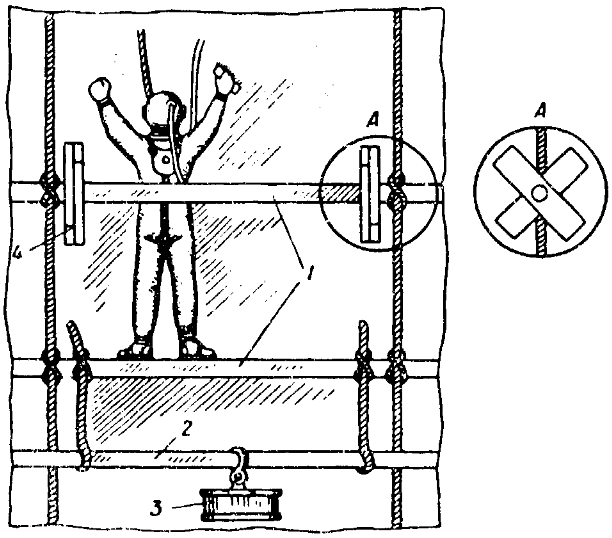


Fig. 1. Wooden Scaffold: 1 - main cross beams; 2 - auxiliary cross beam; 3 - weight; and 4 - cross connection.

The scaffold consists of 2 main cross beams (length 6-7 m) 1 and of one auxiliary cross beam (length 4-4.5 m), 2. The main cross beams are attached to the under-keel hemp ends from the ship's side, while the auxiliary cross beam is fastened to the main (lower) cross beam and serves for balancing the scaffold and suspension of ballast

3, in order to impart a negative buoyancy to the scaffold.

In respect to height, the cross beams are arranged 1-1.2 m apart in order that the diver could work conveniently. The under-keel ends should be of soft material (hemp or capron). In order that the scaffold would not press too much against the side and would not cause inconveniences for the diver during his work, to the ends of the upper cross beam 1, we fasten the crosspieces 4 made of framing pieces with a dimension of around 1000X150X25 mm (Fig. 1).

For the accomplishment of small jobs, use is made of the suspended cages. The cage is attached to the 2 under-keel ends. A weight is attached under the cage to provide it with negative buoyancy.

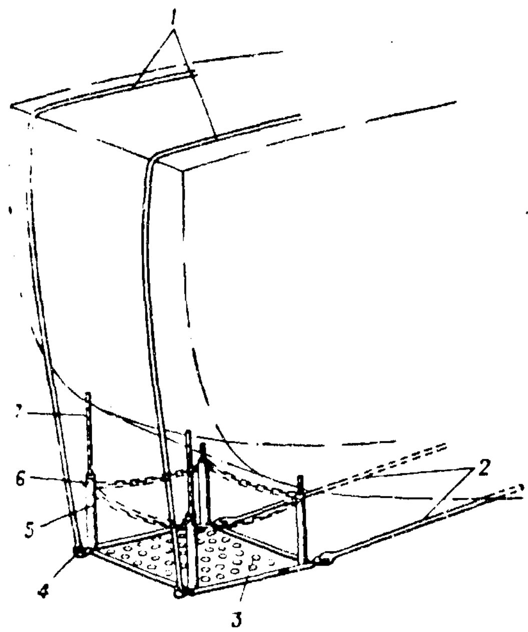


Fig. 2. Metal Scaffold with Extendable Supports for Working Beneath the Bottom of a Ship:
1 - cables; 2 - under-keel ends; 3 - floor (platform); 4 - eye; 5 - columns; 6 - shaft; and 7 - extendable support.

The metal and composite scaffolds (Figs.2,3) are employed in the performance of the underwater tasks requiring reliable support, e.g. during drilling, welding, cutting and the like.

The most common design of metal scaffolding for working at the side of a ship is a metal platform rigged with tubular supports. In order for the scaffold to become lowered readily under the water, its frame is made of rods or of perforated sheets. A guard rail is made on the scaffolds; the front rail can be opened.

For working under the bottom of a ship, use is made of a scaffold having a somewhat different design. To the platform's frame at angles, we weld some tubes with extensible supports. The scaffold is brought to the work site with ropes (slings), the diver extends the supports and resting them against the ship's bottom, he fastens them with plugs or with clamping screws (Fig.2).

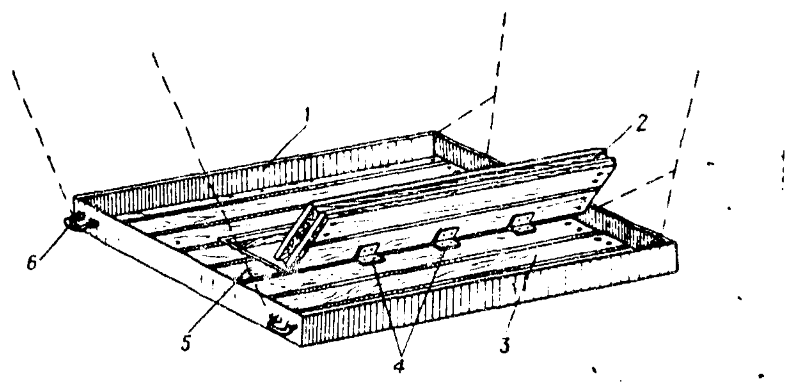


Fig. 3. Scaffold with Tilting Area for Working Under the Stern Overhang (for repairing a vertical rudder): 1 - frame; 2 - tilting section; 3 - wooden flooring; 4 - hinges; 5 - sling; and 6 - attachment rings.

For working under the stern overhang during rudder repair, use is made of a composite scaffold with a hinged section (Fig.3). This scaffold is positioned in such a way that the rudder fin would be in the center of the scaffold's platform. This creates convenience for the divers' work.

During work on the sea floor, for instance in looking for sunken objects, the diver has a runner (leading part of rope), attached to the sliding end, usually near the ballast. This provides the diver with the opportunity of moving freely about the sea floor without losing contact with the diving boat (Fig. 4).

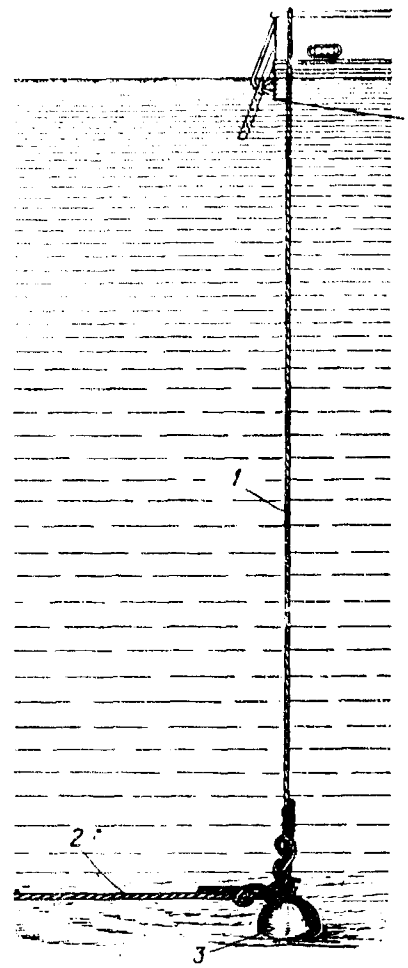


Fig. 4. Submerging End and Diver's Line: 1 - submerging end; 2 - runner (rope lead); and 3 - ballast.

If the diver has been working at a considerable depth (more than 12.8 m), he is brought to the surface by stages, with delays at varying depth in accordance with special tables. In this case, the diver transfers to a decompression chamber which is lowered over the side along with the sliding end. The sliding (launching) line is usually made of manila rope with a circumference of 75-100 mm to which some ballast weighing 50-75 kg is fastened.

During the work from a diving boat or ship with a high side, for lowering the diver, use is made of the diving ladders, the bottom steps of which extend under the water. In the case of performing the work at night or in muddy water, general illuminating lamps are utilized (type PF-1 or VF-56), while the diver is provided with a hand lantern.

**Caissons.** Caissons (box-caissons, microcaissons) are used in the patching of holes located at the level of the effective waterline or beneath the water at a depth up to 1 m. The box-type caisson (see Fig. 5 below) is made from clean trimmed boards, and has three sides plus a bottom. The ends of the side walls and the bottom are cut to fit the ship hull configuration at the place of installing the caisson and the joints are sealed with a cushion of black oakum, edged with sailcloth soaked with minium. The slots in the box are carefully calked. In order to provide great strength and to assure the placement of the box caisson, to its back wall and bottom from the outer side, we attach two beams each and lugs are attached to these beams.

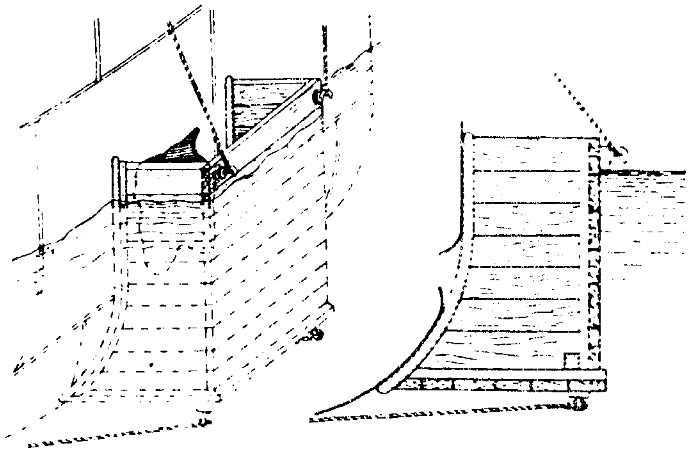

Fig. 5. Caisson (box-type cofferdam).

For the placing of the box caisson under the ship's hull, the diver pulls through the under-keel ends. On deck, the ends are tied to the bottom lugs of the caisson. On the cables, attached to the top lugs, the box-caisson is lowered with a boom, crane or other hoisting device over the side and is submerged in the water. Simultaneously, the under-keel ends are selected from the opposite side; after delivering the box-caisson to its work site, these ends are fastened tight and the caisson is pressed against the ship's side.

In order to lower the caisson more easily into the water, it is loaded with ballast before it is moved. After the placement of the caisson, water is pumped from it and the ballast is removed. The repair tasks are conducted in a conventional manner.

**Patches.** Patches of various types and patch-boxes are utilized for the temporary sealing of holes and other openings in a ship hull. The rigid patch (Fig. 6) is made in the form of a shield of planed boards according to the size of the hole and is coated with red lead (minium). On the shield (screen), we place red lead-soaked sailcloth with an overlap of 300-350 mm on the side; above the sailcloth, boards are nailed across, and along their edges, oakum is placed in a roll along the perimeter and is stitched with the lowered ends of the sailcloth. The patch connects as a soft cushion against the roughnesses in the sheathing of the ship's hull. For fastening the patch to the hole, one passes hooked bolts into the hole or lugs are driven in downward into the beams, and the tightening cables are attached to the lugs. The bolts are placed on gaskets to avoid the filtration of water.

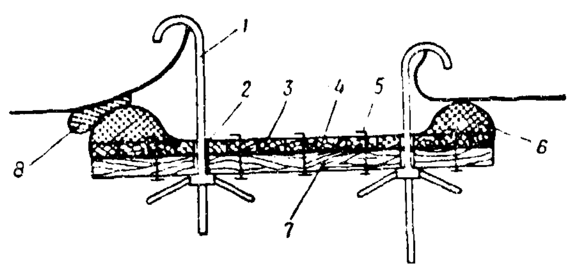


Fig. 6. Rigid (stiff) Patch: 1 - hooked bolt; 2 - hole for bolt; 3 - first row of boards; 4 - sailcloth; 5 - nails; 6 - oakum cushion; 7 - second row of boards; and 8 - mat.

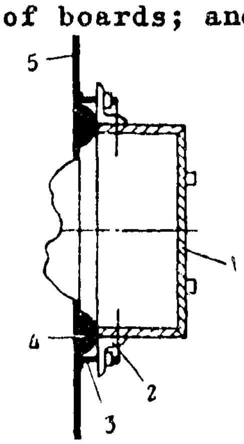


Fig. 7. Patch-Box Mounted on Dowels: 1 - patch-box; 2 - angle-bracket; 3 - dowels; 4 - cushion made of oakum and canvas; and 5 - sheathing of ship.

For sealing the side openings during the repair of the kingston valves and of the other side fittings, use is made of a rigid patch-box, i.e. of a patch with sides (Fig. 7 above). The patch-box is mounted on stretching cables or on dowels. In this case, from the outside, an angle bracket with holes is attached to the side of the box. Around the perimeter of the hole or of the side opening, according to the side of the patch-box, the diver welds dowels to the ship sheathing, or drives them in with the PDP pistol; the patch-box is attached to the dowels.

Section 2. Rigging Tasks Involved During Underwater Ship Repair

The rigging tasks during underwater ship repair are performed in the moving of scaffolds, the placement of patches, box-caissons, the removal and installation of screws, shafts, rudders, various parts, instruments and devices.

For the achievement of the rigging activities, use is made of the various hoisting equipment accepted in naval practice and ship repair, beginning with the single-pulley block-and-tackle units up to a floating crane, depending on the nature of the operations and the weight of the parts involved. For the suspension of loads and placing them in a sling, use is made of steel, fiber and synthetic cables, clamps, collars, snatch-blocks and so forth.

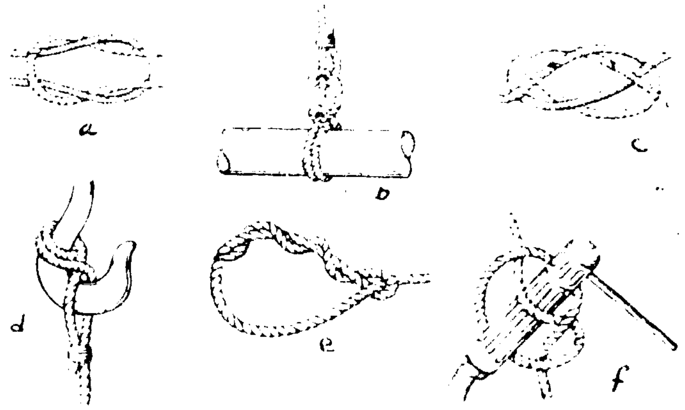


Fig. 8. Marine Knots: a - square knot; b - clinch knot with 2 turns; c - double carrick bend; d - hook knot; e - "half-hitch"; and f - fid-type knot.

In the underwater ship repair practice, use is made of a 6-stranded flexible steel cable with a hemp core; for the application of lashings, use is made of seized rope.

The permissible loads on the cables and on the slinging systems are listed in appendixes 1, 2 and 3.

For connecting the cables which are not subjected to heavy strain, we employ a square knot (Fig. 8a); for the cables subjected to severe strain and the slinging of parts, we utilize the clinch knot with 2 turns (Fig. 8b). The double carrick bend (Fig. 8c) is utilized for joining ropes of varying material and of various sizes (circumferences). For fastening parts to a hook in case of heavy strain, use is made of the hook-type knot (Fig. 8d). For the fast slinging of parts, we use the "half -hitch" (Fig. 8e), while we employ the fid-type knot for slinging the tools for delivery to a diver (Fig. 8f).

In order that the ends of the working cables would not wear out, use is made of replaceable light-duty slings. The light-duty slings are segments of cables, in which 2 loops are made in each, with fastening eyes (Fig. 9a). Use is also made of general-purpose straps (slings) (Fig. 9b), the ends of which are spliced together.


а a) б b)

Fig. 9. Slings (Straps): a- light-duty sling; and b - general-purpose sling. Key: A) splice.

For the slinging of propeller screws, use is made of a main cable fastened by a knot to the base of the blades (Fig. 10). For simplifying and accelerating the tasks, use is made of connecting clamps and yokes. The clamps connect the cables and slings, while the yokes are utilized for slinging the propeller shafts, the deadwood hubs and other parts of round section (Fig. 11). In order to avoid damaging the finish of the propeller shaft, rubber lining is wrapped under the collar (yoke).

The connecting rigging clamps are made with varying load capacity; their design differs in the fastening of the pivot bolt (GOST /State Standards/ 2476-56). The number of the clamp matches its load capacity. For example, No. 21 indicates that the clamp's lifting capacity is 21 tons.

### Section 3. Inspecting the Submerged Part of a Ship Hull

The diver's inspection of the underwater section of a ship hull is performed for maintenance purposes, in the presence of damages, prior to placing the ship in a dock, in preparing a ship for a long voyage or upon return from one.

During the investigation of damage, one determines its extent, location and nature. In studying damage incurred to the sheathing, special attention is paid to the joints (seams), slots, and to the occurrence of dents and cracks. During a technical inspection of the submerged portion of the hull, one checks the stern overhang, especially in the area of the propeller screws' installation.

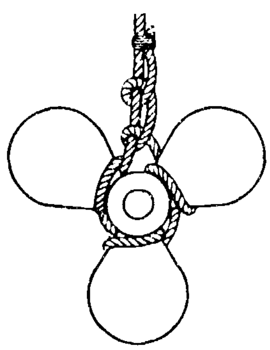

Fig. 10. Slinging of a Propeller Screw.

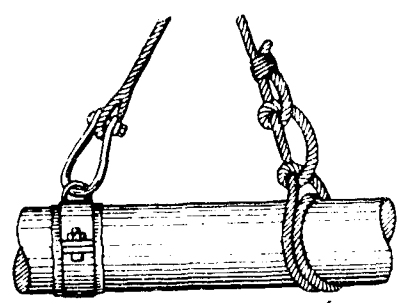


Fig. 11. Slinging of a Propeller Shaft: a - with the aid of yoke and bracket; and b - with the main rope, tied with a clinch knot.

In certain cases, in the places damaged by corrosion, a test drilling is made, and through the hole, one measures the sheathing thickness. The measuring tool (Fig.12) consists of the hollow cylinder 3, having a longitudinal slot on one side, and a longitudinal channel on the other side. Within the cylinder, one can move rod 2 having a bent sharpened end. Lug 1 is soldered to the cylinder. In order that the rod would not turn, pin 5 is screwed into it, entering the slot on the cylinder. To the cylinder is fastened ring 7 with locking device 6 and with projecting-indicator 4, sliding along the groove (slot). Along the groove on the cylinder's surface, a scale of divisions by millimeters is etched. The ring slips freely along the cylinder and can be held in position by the locking device.

Measurement of the sheathing plate's thickness is conductod in the following manner: the diver cleans the sheet at the indicated point of measurement, removing the fouling and rust, scale and old paint. With a pneumatic or electric drilling machine, the diver drills a test hold with a diameter of 10-12 mm so that the curved end of the rod would fit into it without difficulty. The rod is introduced into the hole, until resting on projection 1, into the sheet's outer surface. The curved end of the rod is pressed against the sheet's inner surface. The locking ring 7 is brought tight against lug 5, and is fastened with locking device 6. After this, rod 2 is raised higher and taken out of the hole.

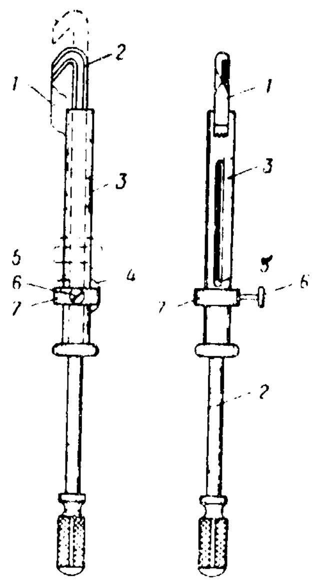


Fig. 12. Instrument for Measuring Thickness of a Sheet: 1 - projection; 2 - rod; 3 - hollow cylinder; 4 - projecting-indicator; 5 - pin; 6 - locking device; and 7 - ring.

The diver places the device on the surface where rod 2 is again set in a position at which pin 5 rests in locking ring 7. The distance between the sharpened end of rod 2 and projection 1 of the cylinder equals the thickness of the sheet.

To avoid the entrance of a large amount of water, the hole in the sheathing is covered with a previously prepared wooden plug (dale plug).

After measuring the sheathing's thickness, the test hole is welded shut or a false rivet is driven in. The water which has leaked in is pumped out with the onboard water drainage equipment.

During the inspection of the screws, attention is turned to the condition of the blades, the presence of keying, fastening of the fairing (whether there are any cut-off bolt heads, nuts etc.). In the inspection of the propeller and rudder units, one checks for the clearance between the sleeve and the propeller shaft; the condition of the gudgeons and pintles on the rudder-post; the position of the rudder (absence of sagging), and so forth.

During the inspection of the side openings, special attention is paid to the presence and technical condition of the protectors, and to the extent of the screens' fouling.

The diving inspection is usually conducted from an under-keel sling (see Fig.13 below). The tasks involved in a diving inspection are performed by the director or a senior specialist from the USRS (Underwater Ship Repair Station). On the basis of the material obtained during the inspection, a technique is develcped for the repair, and the required drawings or sketches are drafted.

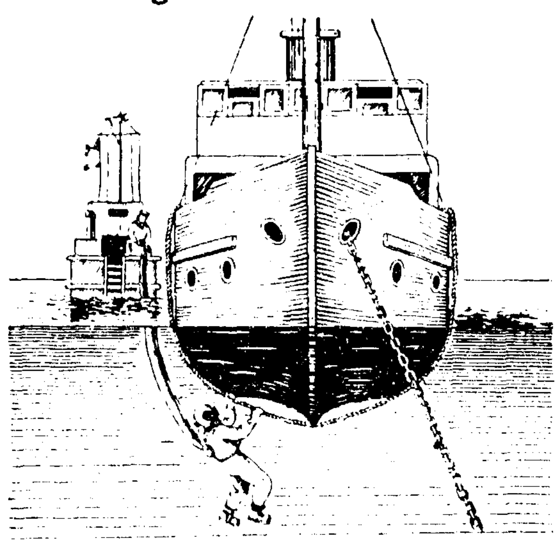

Fig. 13. Inspection of the Submerged Part of Ship's Hull by a Diver Using an Under-Keel Sling.

Inspection with the use of television permits us to solve, under the conditions of ship repair and of emergency life-saving work, the problem of the objective determination of the hull's condition and the position of a ship in distress, sometimes without the participation of a diver.

At the present time, the domestic (Soviet) industry is making a number of units for underwater TV, developed by the Institute of Oceanography at the USSR Academy of Sciences (IOAS), and is also producing the type PTU-5 underwater TV sets. The transmitting TV cameras are manufactured in two types: portable, of light weight for carrying by the diver, and the heavy deep-water type with a remote control mechanical system.

For the underwater ship repair, it is most advantageous to utilize the special PTU-5 unit or the type IOAS set.

The PTU-5 underwater TV unit (Fig. 14) consists of an airtight transmitting camera 1 with illuminators, of an activation unit 2, of an amplification and shaping unit 4, of a power supply unit 3, a control panel 5, and of the TV set (videoreceiving device), 6.

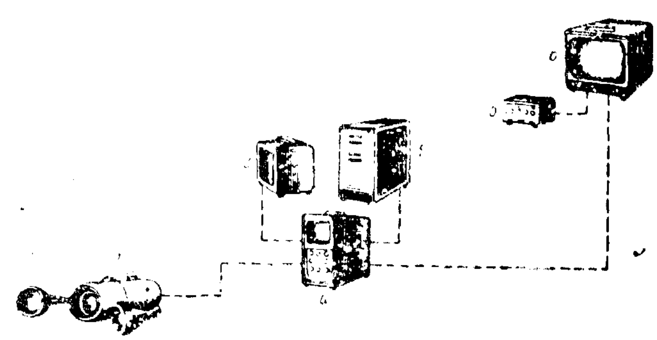

Fig. 14. PTU-5 Underwater TV System: 1 - camera in sealed housing with illuminators; 2 - activation unit; 3 - power supply unit; 4 - amplification and shaping unit; 5 - control panel; and 6 - video-receiving device.

All the units in the system except the TV camera are located on the surface and are installed on the ship being repaired or on some other ship. The power is fed from an AC network with a voltage of 220 v. The current being consumed is approximately 1 kw.

The quality of the picture depends on the illumination of the object and the transparency of the water. At depths up to 12 m, the contrast images are obtained for a distance of 3-6 m.

For increasing the state of contrast, use is made of the so-called brightening attachment, i.e. a transparent space, hollow, filled with distilled water or glycerine.

The TV camera can be situated at a distance up to 400 m from the power source and the amplification unit. For practical purposes, this is quite adequate for inspecting any part of a ship hull, the conduct of inter-operational monitoring and evaluation of the work performed under water.

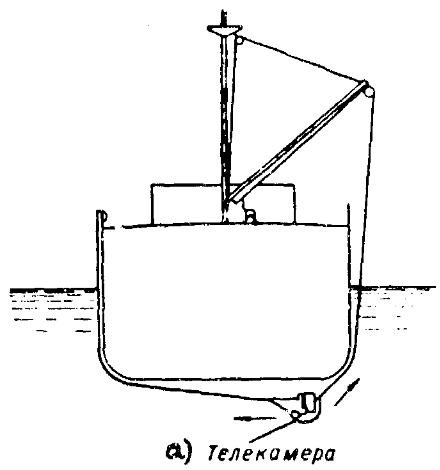


Fig. 15. Inspecting the Ship Hull with the Aid of a TV Camera Suspended on an Under-Keel Sling.

Key; a - TV camera.

The underwater TV system can be used for the inspection and official examination of the underwater part of the outer sheathing of a ship, the rudders, the propeller screws, the side fittings, etc.; for establishing the sizes of the holes, the quality of the welding operations during the installation of patches and of doubling sheets; for observing the progress of work on the propeller unit, especially during the removal of the screws, withdrawal and movement of the propeller shafts, the extrusion and intrusion of the deadwood sleeves; for observing the placement of a ship on keel-blocks and cages during the docking operation, and so forth.

In individual cases when it is not possible to send a diver down, the inspection of the condition of the bow and of the central (cylindrical) part of a ship can be done with a TV camera, by pulling it under the keel with the aid of a hauling sling from the upper deck (Fig. 15). In this case, the under-keel sling serves as a guide. As needed, the under-keel sling is shifted along with the suspended camera to another section.

The inspection of the stern end is conducted with the aid of a diver. If for any reasons, a diver can not be sent down, but an inspection of the stern must be made, the TV camera is shifted from side to side on the upper deck and each side is inspected separately.

# CHAPTER 2

## REPAIR OF THE PROPELLER UNITS

The repair of the propeller units will be divided into the repair of the propeller screws, including their disassembly and assembly; withdrawal and installation of the propeller shafts; extrusion and insertion of the sleeves to the deadwood and shaft brackets; and laying out the shaft's axial line.

### Section 4. Repairing the Propeller Screws without Removal from the Shaft Cone

The following tasks are included in the repair of the bronze or steel propeller screws while the ship is afloat, without removal from the shaft cone: straightening the blades, trimming and filing the damaged edges, preparation and attachment of pieces to the damaged blades, and replacement of the blades (if the design of the screws permits).

In case of minor damages, the straightening of propeller screw blades is done manually by the diver. At considerable camber of the blades (more than 250 mm around the circumference and a bending angle in excess of 20$^{\circ}$), the screw is removed and the work involved in straightening and balancing it is done in the shop.

Straightening the blades under water is accomplished in 2 steps: rough and finish. Initially, from his scaffold the diver straightens the screw with 2 sledgehammers. One hammer is held under the bent blade, while the other, used to strike the blade, restores it to its previous shape. The final straightening is accomplished with a small hammer while a sledgehammer is held under the blade. If the screw is large, during the final straightening, in place of the sledgehammer it is better to use a template taken from a spare screw, or a special plate. The mass of the template should be larger than the mass of the sledgehammer, otherwise the template will move away during the blows. As a rule, this work is done by 2 divers.

In the case of minor damages (dents, burrs and the like), the edges of the propeller blades are filed or trimmed with a hand chisel followed up by a filing. In the case of major damages to the propeller blades, the damaged parts are removed by electric arc or by oxy-electric cutting.

If the screw is made of steel, on the basis of a pattern, to replace the damaged part, a piece is fabricated in the shop; this piece is then welded to the blade under water. For this purpose, the point of cutting is cleaned carefully; if the metal thickness at the point of welding is considerable, the chamfers (bevels) are removed. After welding the piece on, the joint is trimmed with a chisel flush with the surface, is cleaned and brushed. If the screw is made of bronze or there is no possibility of fabricating a piece or of replacing the screw, the trimming of all blades is performed according to the size of the damaged blade.

The repair and trimming of the blades is used under conditions when a ship is away from base. If the design provides for the replacement of the blade, in the case of appreciable damages, given the availability of spare blades, the old ones are replaced.

The removeable blades have flanges and are attached by dowels or bolts to the propeller hub. The dowel heads are covered with cement or are retained with a cotterpin.

For removal, the blade is slung with a cable lowered from the deck, the cotterpins are pulled, and the locking strips or dowel heads are cleaned of cement; using a wrench, the diver then unscrews the pins and the blade is raised to the surface.

The pins are often "seized" and then break. In this case, the bits of the pin are removed from the recess but in doing so, one should protect the inside thread in the hole as much as possible. This job is very laborious and requires high skill. For this purpose, with an angle drill or with a pistol type of drill, a hole is drilled in the center of the pin, the hole size being less than the pin's diameter; into this hole, a triangular or square rod is driven tightly. To the end of the rod, a crosspiece (handle) is welded, and the fragment of the pin is screwed out of the hub.

If the pin (dowel) fragment is not screwed out, in the drilled hole, with a tap threaded in the opposite direction, we cut a thread and an auxiliary pin is screwed in. Usually, with the help of the auxiliary pin, we can manage to remove the fragment; however, if even this method fails to yield satisfactory results, the fragment is drilled out with a pneumatic or electric drill, the hole is re-threaded and a new pin is made to fit the threaded diameter of the hole. When necessary, one performs a boring of the appropriate hole in the blade's flange.

At its ends, the new blade is fastened to the propeller hub, is moved by the diver to the site and is attached with dowels. Then, depending on the design, cotterpins are inserted or locking strips are installed.

The dowel heads are covered with brand 400 Portland cement. Under the underwater conditions, this can be described better as a smearing with cement. The cement solution is prepared at the surface, mixed to the consistency of a thick paste and delivered to the diver in a closed bucket. In order that the cement would not wash away, the smear is covered with canvas or other cloth, and bandaged. The canvas is removed when the cement has hardened.

Section 5. Removal of Propeller Screws from Shaft's Cone.

Preparatory Tasks Prior to Removal of Screw from Cone

Before the removal of the screw, it is necessary to determine its design, attachment to the shaft's cone, verify the presence of a protective casing covering the shaft's neck, the presence of a fairing (or of a streamlined cap nut), determine the size and number of locking devices, and so forth. In case of the application of the explosion method, it is necessary to measure the screw's depth in the water and its distance from the sheathing.

The inspection and the subsequent operations on the removal of the screw are performed from a scaffold. In this connection, one preselects the necessary tools, cables and attachments. After that, the propeller shaft is disconnected from the intermediate one and is blocked with wooden supports (see Fig. 16 below).

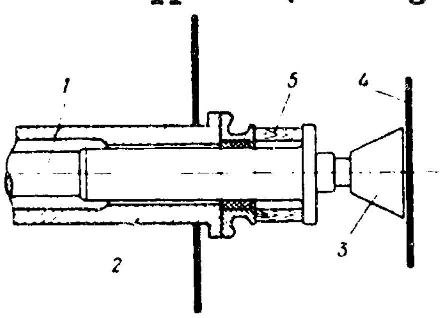


Fig. 16. Diagram of Propeller Shaft's Installation: 1 - propeller shaft; 2 - stern tube; 3 - dum-craft; 4 - support; and 5 - wooden stays.

Before the removal of the fairing (of the cap nut), with a chisel or punch, marks are made on the cowl (cap nut) and on the propeller hub so that during reassembly, one would preserve the correct setting of the fairing or tension of the cap nut. Then the diver unscrews the locking bolts or screws retaining the fairing or the streamlined cap nut.

On the screws which turn to the right, the cap nut has a left-hand thread, and vice versa. For turning off the cap nut, one uses a long-handled wrench or a ratchet wrench and the nut is tied to a rope sling lowered from the upper deck. At a signal from the diver, with the aid of a capstan, winch or by hand, the sling is hauled and tightened. For facilitating the movement of the streamlined cap nut, simultaneously with the sling's tightening, the diver strikes the key with the sledgehammer. Then the diver resets the key when it reaches the extreme position and he sees to the removal of the cap nut.

When the cap nut has been loosened sufficiently so that its removal is possible by hand, the key is raised, while the diver (having slung the cap nut), turns it off the rest of the way and moves it out from under the stern for hoisting upward. The shaft thread is then coated with a lubricating grease, wiped with a cloth and wrapped with a thin rope.

If the fairing does not have faces but is fastened by locking devices to the propeller hub, the diver ties the fairing by the eye bolt screwed into the place of the plug covering the hole for the injection of grease. The removed locking devices, bolts and nuts are collected in a pail to avoid their being lost.

In case of removing or drilling out the plugs (retainers), for working convenience, at the diver's command the propeller shaft is turned manually to the proper angle and is locked in place once more.

On the auxiliary and merchant ships, the steel fairing is often welded to the propeller hub. In this case, the fairing is cut loose by oxy-electric cutting at a slight distance from the propeller hub. In bringing such a fairing to the surface, we lap-weld to it an intermediate strip which is then fitted to the remaining uncut part of the fairing and after being clamped, it is joined with a fillet weld. Sometimes a new fairing is prepared to replace the one which has been disassembled. The remnants of the old fairing are cut away with a chisel, the propeller hub is cleaned and a new fairing is fitted to it. After seating the screw on the shaft's cone and the turning of the tightening nut, the fairing is welded to the hub.

After removal of the fairing, the release of the grip nut is accomplished. First we twist out or drill out the plugs, remove the tightening strip, and then we unscrew the grip nut. To avoid errors, prior to using the wrench, the direction of the nut's threads is checked.

The sequence of turning the stop nut is the same as for the streamlined cap-nut. If the nut has "jammed" and can not be removed with a wrench and with blows from the sledgehammer, the explosion method is utilized. In this case, to the wrench handle we connect an additional pipe with a small area reinforced by a stiffening rib at the end. On this area, we place an explosive charge weighing 30-40 grams. The diver gets out of the water and the explosive is set off. If the explosion proves insufficient, it is repeated with a charge of increased weight. After the stop nut has been moved, it is turned several times and is left on the thread up to the moment of moving the screw from the shaft's cone (in the impact method of removing the screw); it is then tied to a sling, turned off completely and raised to the surface.

In the installation of the stop nut or of the streamlined cap-nut, the tasks are performed in reverse order. In the case of drilling the plugs out, new threads are tapped in the holes, new plugs are made, and holes are drilled in the fairing.

**Removal of Propeller Screws**

Removal of the propeller screws is conducted chiefly with two procedures, i.e. traction and impact. The traction method can be subdivided into mechanical and hydraulic.

In the practice, use is often made of the combined technique of disassembling the screws, with juncture of the traction and at the same time of the impact, e.g. explosion, procedure. In this instance, the initial tightness is developed with mechanical devices while the jolt providing the movement of the screw is provided by an explosion.

**Removal of Propeller Screws by Traction Method.** This method is most popular. On each ship, there is a puller (pulling tool), corresponding to the weight of the screw and the design of its attachment. On the small screws, provision is often made on the hub for slotted openings for the attachment of the puller.

The gist of the traction method consists in the idea that the puller is connected to the hub or to the screw blades and owing to the thrust in the end of the propeller shaft, a contracting force is generated, acting along the axis of the shaft. After the puller overcomes the adhesion force of the propeller hub, the screw is moved with the shaft's cone. In distinction from the impact procedure, the traction method is characterized by the static application of force and by its gradual increment.

The traction method has several modifications depending chiefly on the screw's weight and design: removal with the aid of a strip, clamp, hooks, with a sleeve; by hydraulic force, i.e. by pumping liquid into the inner hub cavity, or by a hydraulic block and a piston-type puller.

The mechanical techniques of removing the small and medium-sized screws with a strip and aleeve are shown in Figs. 17 and 18. Depending on the conditions, one is sometimes limited to the utilization of only the support strip; in this case, the tightening force is developed by the uniform tightening of the nuts.

In the removal of the screw with hooks (Fig. 19), to avoid skewing, the hooks are mounted on each blade. It is best to connect the hooks to the hub, provided that the screw design so permits. In order that the support strip would not be deformed, it should be made of thick steel of extra strength not less than St-5.

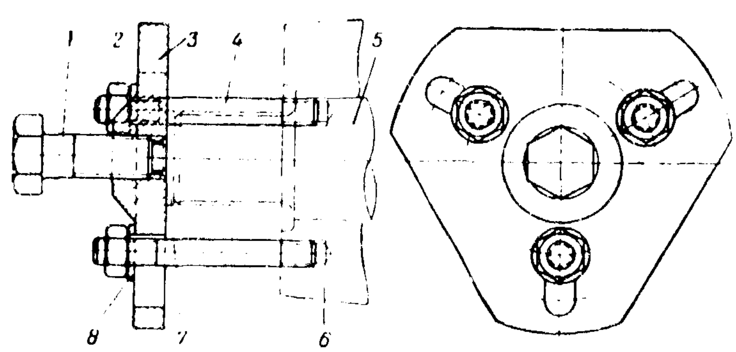


Fig. 17. Removal of Propeller Screw with Strip and Pressure Bolt: 1 - pressure bolt; 2 - nut; 3 - support strip (flange); 4 - pin; 5 - propeller shaft; 6 - propeller hub; 7 - steel lining; and 8 - washer.

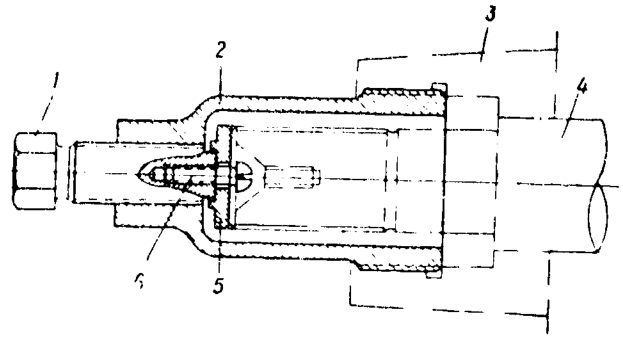


Fig. 18. Removal of Propeller Screw with Sleeve (in presence of inside threading on end of propeller hub): 1 - grip bolt; 2 - sleeve (puller); 3 - propeller hub; 4 - propeller shaft; 5 - support washer; and 6 - mounting bolt.

The hydraulic method of removing the screws consists in the idea that all the loose spaces between the propeller hub and the shaft cone are plugged with lead or with red copper foil, and into the hub cavity through a tube we pump oil or kerosene and a pressure up to 100 kg/cm$^2$ is developed. The oil entering between the propeller hub and the shaft cone weakens the forces of adhesion and the screw is removed. This procedure is frequently combined with the application of mechanical devices.

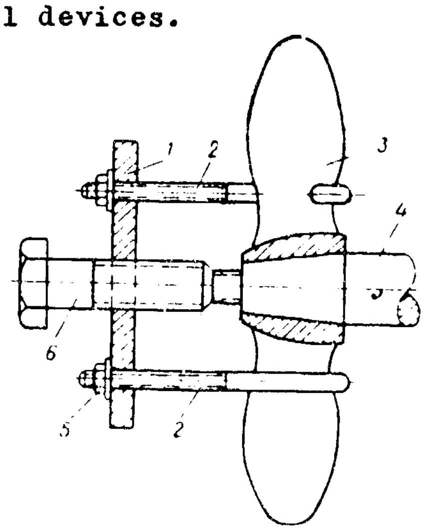


Fig. 19. Removal of Propeller Screw with Hooks: 1 - pressure strip; 2 - hooks; 3 - propeller screw; 4 - propeller shaft; 5 - nut; and 6 - mounting bolt.

The method of removing the screws with a hydraulic block (Fig. 20) has gained wide acceptance. The packet 6 of red copper 1 mm thick is placed between the steel disks 7 and 5. Disk 5 is pressed against the end of propeller shaft 4. With pins 2, disk 7 is fastened to the hub of propeller screw 3. By means of the red copper tube 1, packet 6 is connected with a hydraulic pump, and into it oil is pumped under a pressure of 90-100 kg/cm$^2$. Usually such a pressure is sufficient for the initial displacement of the screw. The technique is simple, productive but it does have disadvantages, e.g. the hydraulic packet (block) often goes out of commission, breaking along the joint.

For the removal of the screws having medium and considerable weight, use is made of a hydraulic piston-type puller with an adapter which is made each time for the actual screw. The puller consists of housing 6 (Fig. 21), piston 8 with packing collar 3, of collar 4 with fittings for suspension. By tube 1, the puller is connected with a manual hydraulic pump.

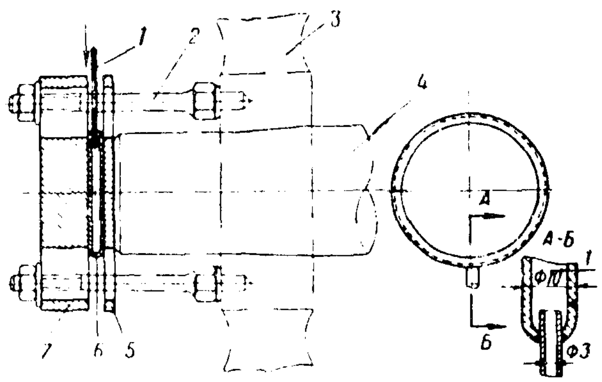


Fig. 20. Removal of Propeller Screw by Hydraulic Packet: 1 - red copper tube; 2 - extruding pin; 3 -propeller hub; 4 - propeller shaft; 5 - intermediate disk; 6 - hydraulic packet; and 7 - supporting disk.

To the propeller's hub, there is fastened an adapter with an intermediate threaded bushing. The puller is then applied at the end to the screw and is turned into the bushing of the adapter. After the puller has been set up, a pump is used to force machine oil (T grade) into its cylinder; pressure is created between the end wall of the cylinder and the piston, which abuts against the end of the propeller shaft. Through the adapter, the piston cylinder is connected with the propeller hub. In this manner, the oil pressure in the cylinder creates the required contracting force along the shaft's axis, and the propeller screw is displaced.

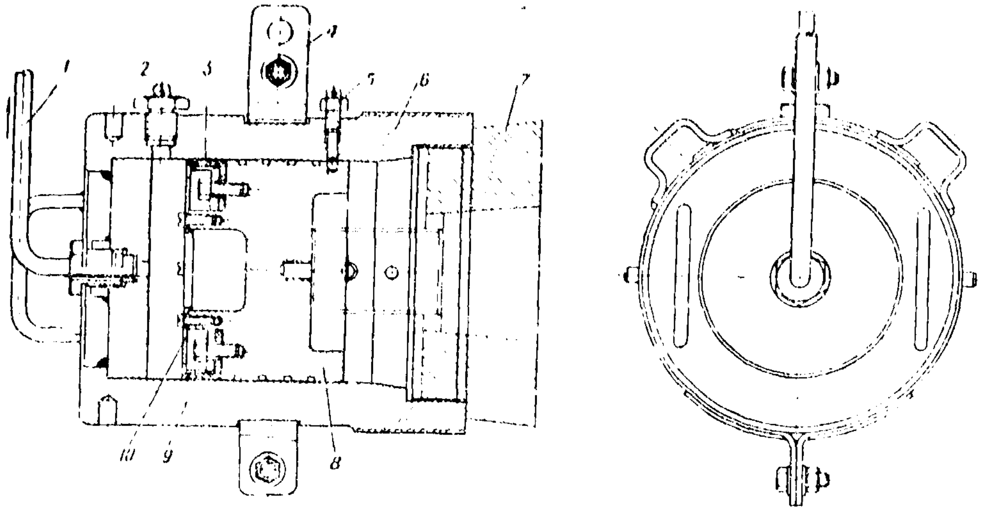


Fig. 21. Hydraulic Piston-Type Puller for Removing Propeller Screw: 1 - red copper tube to the hydraulic pump; 2 - plug; 3 - leather packing ring; 4 - clamp made from two halves with eye bolts; 5 - set bolt; 6 - frame of puller; 7 - hub of the propeller screw; 8 - piston; 9 - spacing rings; and 10 - disk-type stop.

The puller develops considerable force and functions without breakdown since the pressure in the puller can be raised to 550 kg/cm$^2$.

Removal of propellor screws by the impact method will be divided into the wedge-type, in which the displacement of the screw is accomplished with the spacing wedges, and the explosion-type, in which the momentary action of the spacing force is developed from the energy of the explosion.

The wedge-type technique of disassembling the propeller screw (Fig. 22) is utilized in the cases when access to the screw is convenient, and consists in the following steps: between the propeller hub and the mortar (?) of the deadwood or the propeller struts (brackets), we insert two steel wedges 1, which are then spaced by the central wedges 2. The screw is moved from the shaft cone owing to the spacing force which is being developed. Wedges 2 are pounded in with a sledgehammer or with a metal rod weighing 60-70 kg (with a bar), lowered from the upper deck along the guide pipe having a diameter of 180-200 mm, mounted along the wedge's axis. Holes are made in the pipe in order that the water would not muffle the blow.

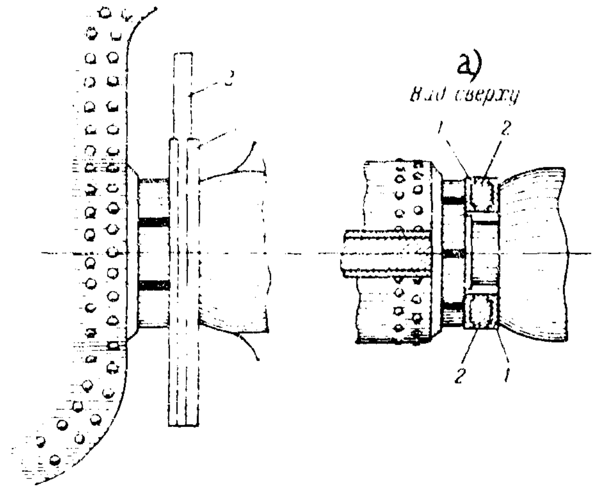


Fig. 22. Wedge Method of Removing Propeller Screw. Key: a) view from the top.

Prior to the removal of the screw, the diver checks the amount of the clearance between the bow edge of the propeller hub and the deadwood or strut. If the clearance is slight, after uncoupling from the intermediate shaft, the propeller shaft is extended sternward for 80-90 mm and blocked in position.

The disassembly work on the screw is performed in the following sequence. On the shaft's cone and the hub, the diver makes marks establishing the seating and the mutual positioning of the screw and the propeller shaft. Two sets of wedges are delivered alternately from the deck; these are installed by the diver from two sides along the shaft's diameter for creating a uniform thrust; blows are applied alternately or, if the work is conducted "with a bar" from on deck, the blows are delivered simultaneously on both wedges.

After the screw has been shifted, it is slung from both sides with rope slings fastened on a beam, specially positioned on the upper deck athwart the ship; the sling's ends are suspended on both sides. The slings are drawn (retracted) by block-and-tackle of the appropriate hoisting capacity and the screw is removed from the shaft's cone. In order to make the withdrawal of the screw from under the stern overhang more convenient, a rope sling is also run out from shore or from another ship and the diver steadies and guides the screw.

On certain ships, especially those equipped with single-shaft units, the distance between the terminal part of the propeller shaft and the rudder-post is short and it is not possible to turn the screw out. In this case, the propeller shaft is unblocked and under the diver's instruction is moved toward the ship's bow. The removal of the propeller shaft from under the stern overhang can be obstructed by the rudder fin; in this case, the tiller stops are removed and the rudder fin is turned by $90^{\circ}$.

After the screw has been pulled from the shaft's cone and brought from under the stern, before hoisting up to the surface, it is re-slung from the blades beyond the hub. This needs to be done in order that the screw would not break. In addition, the screw is slung by two blades on either side, which makes its hoisting difficult, but one should never hoist a screw that is tied only by one blade. For the re-slinging, slings are pulled in from both sides, the propeller screw is lowered onto a scaffold or the sea floor (if the work is done from the bottom), and the diver re-rigs the sling on the screw. If the screw can not be accomodated on the scaffold, an extra line is run from the upper deck; with this line, the diver ties the screw by the hub, and after the screw's weight has been transferred to this line, ropes are paid out from the onboard block-and-tackle, and the screw is raised to the surface.

Explosion Method of Removing the Propeller Screw. This technique is utilized when the conventional procedures of removal have failed to produce results, or when the screw's weight is in excess of 1 ton. The essence of the procedure consists in the following steps. Charges (2-4) of explosive material are uniformly placed on the shaft in the space between the bow end of the propeller hub and the deadwood or strut, and these charges are set off. The considerable force of the explosion directed along the axis of the propeller shaft, shifts it from the shaft's cone. In spite of its apparent simplicity, this method requires much attention, carefulness in preparation and strict compliance with the safety rules.

The principal attention in preparing the propeller screw for removal by the explosion method should be diverted to establishing the size and number of the charges. With an accuracy which suffices for the practice, the size and number of the charges are determined proceeding from the mass (weight) of the screw, its material, the permissible loads on the ship hull sheathing, and the submergence depth of the charges in the water.

On the basis of calculations, tables have been developed establishing the weight of the required amount of high explosives (HE) (Appendix 4) and the maximum weight of one charge (Appendix 5). Initially we establish the total amount of HE; then we refine the size and number of the charges depending on the actual conditions. A lesser weight of HE is chosen and accordingly, a larger number of charges is established.

The maximum weight of the HE in an open charge (in a soft container) is permitted up to 70 kg, and in a closed container (wooden block) up to 210 kg. The charges used have the same weight. As high explosive, use is made of TNT, tetryl or ammonite. The TNT in powdered and pressed form has become most popular. From the pressed TNT, with a hack saw we shape a parallelepiped, in the end of which we drill a blind hole into which the electric detonator is inserted. The charge prepared in such a manner is wrapped in paraffin paper (waxpaper) or silky rubber. The ends to the electric conductors of the detonator are cleaned and bent aside.

The HE in powdered form is poured into a small bag made of rubberized silk fabric or other waterproof material; the electric detonator is installed, and the neck of the bag is tied tightly with binder twine or silk thread around the conductors of the electric detonator.

Use is made of the VKM electric detonators with the capsule-detonators, type GRT No. 8, TAT No. 8 or TAG No. 8.

For the explosion-type operations at a depth up to 20 m, use is made of the moisture-resistant electric detonators, type EDCH-16, while in the dismantling of sunken ships at great depth, we employ the type VKM-80 detonators.

The charges of HE are placed in wooden containers (a U-shaped frame) 30-40 mm thick, or are suspended openly on the shaft. To avoid damages, the shaft is wrapped with lead sheet; the bow end of the propeller hub and the deadwood mortar are covered with steel plates, and wooden stays are placed between them (Fig. 23).

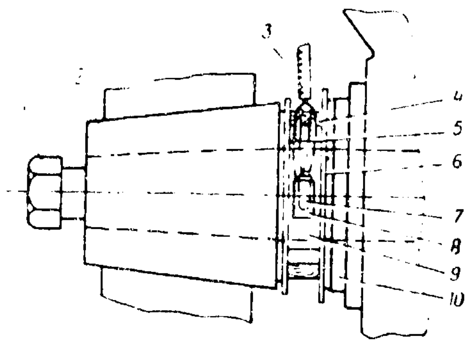


Fig. 23. Placement of Open HE Charges on the Shaft: 1 - grip nut; 2 - propeller screw; 3 - main conducting line; 4 - wooden stays; 5 - lead shield; 6 - iron plate; 7 - detonator; 8 - charge; 9 - propeller shaft; and 10 - deadwood bushing.

In order that the charges would not move away from the shaft, they are rigged with a lanyard and retaining lead weights are also attached. The ends of the lines from the electric detonators (the section lines) are connected in-series with the main conductors and through a knife switch with the power source.

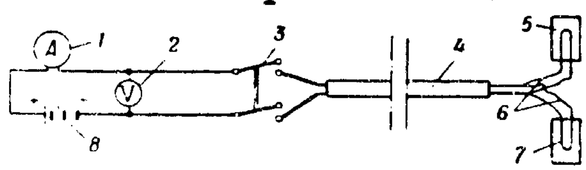


Fig. 24. Diagram of Electric Explosion System: 1 - ammeter; 2 - voltmeter; 3 - knife switch; 4 - main conductors; 5 - charge; 6 - section conductors; 7 - electric detonator; and 8 - storage battery.

The main conductors consist of double-strand wires, brand PRSHM or PRSHUM. As a power source, use is made of the special type PM-1, PM-2 or KPM-2 blasting machines, or of 12-volt storage batteries. The current force(in the electric explosion circuit) amounting to 1-5 amps provides (assures) the setting off of the detonators. The electric detonators are interconnected parallely (Fig. 24 above). The electric blasting circuit is checked for proper condition of insulation and intactness of the conductors; for this, an ohmmeter is utilized.

If the operations are conducted from a diving boat, after the emergence of the diver from the water, the boat is moved to a safe distance. The warning signal is then sounded; after 2-3 minutes, the knife switch is closed and the explosion occurs. If it fails to do so, after 20-30 minutes the main conductors are disconnected from the knife switch, the diving boat approaches the ship, and a diver goes down to make an inspection. If the explosion did occur, a diver is sent down after 10-15 min. in the event that the explosion was only a partial one.

If the screw has shifted from the shaft cone, the driver rigs the sling to the screw, turns off the stop nut, pulls it away and feeds it upward. If the screw can not be removed manually or with light taps from a hammer, the regular puller is used to remove it.

In recent times, the method of exploding the charges with the aid of a blasting fuse has gained wide acceptance. The blasting fuse is fairly safe, burns slowly, can be cut with a knife, has little sensitivity to impact and friction, can stay under water for up to 12 hours, transmits the detonation at a rate of 6800-7200 m/sec, and becomes prone to explode at a temperature above 30°C.

The HE charge is wrapped with the blasting fuse in 3 or 4 coils. The fuse end is brought to the surface, and to it for a distance of 10-15 cm, with insulating tape there is fastened an electric detonator or fuse. In order to activate the fuse, its ends are wound tightly with insulating tape or coated with mastic. The detonating fuse is less risky for the diving explosive-handlers during the placement and especially in case of the disposal of unexploded charges. It is often employed as a backup device for the electric detonators in the removal of the screws by the explosion method.

## Section 6. Installation of Screw Propellers

The installation of the screw propellers is achieved in the following sequence. The propeller shaft is turned with the key upward. The diver inspects the shaft's cone, cleans the algae and other fouling from it, checks for the presence of positioning marks on the shaft, of protective wrapping on the thread, cleans off the working place and then issues the order for the delivery of the propeller.

The prepared propeller is delivered on two slings and is placed on a scaffold. The diver re-rigs it by the blades with the consideration that the key bed (keyway) will be at the top, and he issues the order to raise the propeller. The propeller is then placed on the shaft's cone in such a way that its keyway would line up with the key on the shaft. As soon as the threaded part of the shaft appears, the diver cleans the thread of its wrapping and manually turns on the grip nut or the streamlined cap-nut.

The diver then tightens the grip nut with a long-handled wrench. The tightening of the clamping nut is conducted with the aid of a sling lowered from the upper deck, just as during the unscrewing of the nut. Tightening of the nut is continued until the propeller reaches its place of seating indicated by the mark. The clamping nut is blocked with bolts or with a locking strip and the slings are released.

After this, the fairing prepared for installation is plugged with lubricating grease and is delivered on a sling to the diver. The diver spreads a thick coating of lubricant on the clamping nut and the end of the propeller shaft, adjusts the fairing to comply with the positioning marks, turns and calks the locking device, or fastens it with a cotterkey. If the shaft's neck was covered with protective linings, they are also adjusted in place; the sling on which the fairing was delivered is paid out, the eye-bolt is unscrewed, and a plug unit is inserted in its place.

## Section 7. Removal and Installation of Propeller Shafts

The disassembly of the propeller shafts is usually conducted in conjunction with the repair of the deadwood in the processing of the rockwood, in case of damaged lining of the shaft, and in other similar instances.

Before performing the tasks, one checks the design and establishes the direction of removing the shaft (externally or within the ship). In dependence on this, and also on the dimensions and weight of the shaft, we develop a procedure for the removal, and rigging is prepared (devices, cables, pulleys etc.). Powerful water drainage equipment is prepared from pumping out the water which leaks in as the shaft is drawn and for use in case of an accident. During the entire period of conducting the work, a guard is posted round-the-clock.

Special attention is turned to proper rigging and to the suspension of the shaft, in order to avert damage to its finish, cambers and losses during removal and hoisting to the surface.

The removal of the propeller shafts is usually performed after the removal of the propellers and their disconnection along with the intermediate shafts. On small ships, sometimes for speeding up the operations, the propeller shaft is removed together with the propeller and the fairing. The propellers may also not be pulled during the removal of the onboard shafts in the ships equipped with a two or three-shaft unit, if the shaft's design allows them to be disassembled without pressing out the propeller strut bushing.

The diver attends the advance of the shaft to the interior of the ship's hull and at that instant when the shaft's tail is covered in the deadwood's mortar and becomes recessed by 200-300 mm, he covers the deadwood closely with a special prepared wooden plug (Fig. 25).

The wooden plugs float up and are not very handy for working under water; therefore, for closing the openings with a diameter of 300 mm and more, use is made of composite plugs, consisting of a wooden base and a metal or cement casting (Appendix 6).

If the deadwood bushing is short, at the command of the diver, the removal of the shaft is stopped and the diver pounds the plug in.

If seepage is detected, the clearance between the plug and the deadwood bushing is calked with black oakum.

After the removal of the propeller shaft from the deadwood, on the studs on the inboard end of the stuffing box, we install a metal blind flange fitted with a rubber lining.

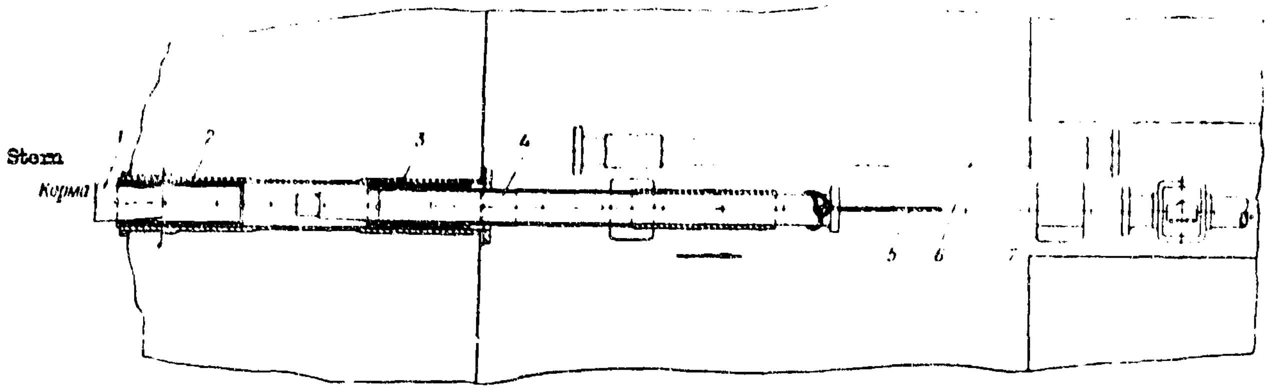


Fig. 25. Removal of Propeller Shaft to Interior of Ship Hull: 1 - wooden plug; 2 - stern deadwood bushing (collar); 3 - bow deadwood bushing; 4 - propeller shaft; 5 - tension cable; 6 - intermediate shaft; and 7 - bearing.

Removal of propeller shafts into the water is performed by two methods: by forcing them out with the aid of a false shaft; and by the traction method with the utilization of caps. On the ships with considerable displacement and having long propeller shafts, use is usually made of the caps, while on the ships of slight and medium displacement, we resort to the use of a false (dummy) shaft.

The dummy shaft consists of a tube (of threaded sections) with a diameter which is 1 mm less than that of the propeller shaft, but is longer than it. Dummy plugs are welded to the tube's ends; one of the plugs serves for connecting the dummy shaft with the propeller shaft, while to the other end we tack-weld heads or make openings for the installation of handles which are utilized for inserting and removing the false shaft.

On the dummy plug designed for connecting with the propeller shaft, a thread is cut corresponding to the diameter and thread of the propeller shaft. After the removal of the intermediate shaft, the dummy shaft is screwed in sections onto the propeller shaft in proportion to its emergence into the water.

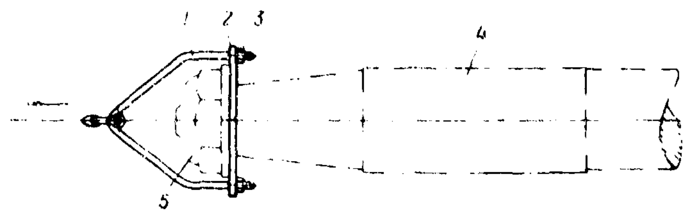


Fig. 26. Collar-type Clamp for Pulling Shaft into the Water: 1 - clamp; 2 - washer; 3 - nut; 4 - propeller shaft; and 5 - locking nut.

To the propeller shaft's shank, we fasten a clamp (collar), and to it we rig a pull cable (Fig. 26). For supporting the shaft in proportion to its emergence from the deadwood's mortar, slings are lowered from the upper deck, with the use of block-and-tackle or booms. If conditions permit, on the small ships the shaft is pulled along with the propeller. If the work is performed during the winter, the supporting blocks are placed on scaffolds set up on the ice (Fig.27). The number of the block-and-tackle units and their hoisting capacity are chosen in dependence on the propeller shafts' length and weight (there should be a minimum of two units).

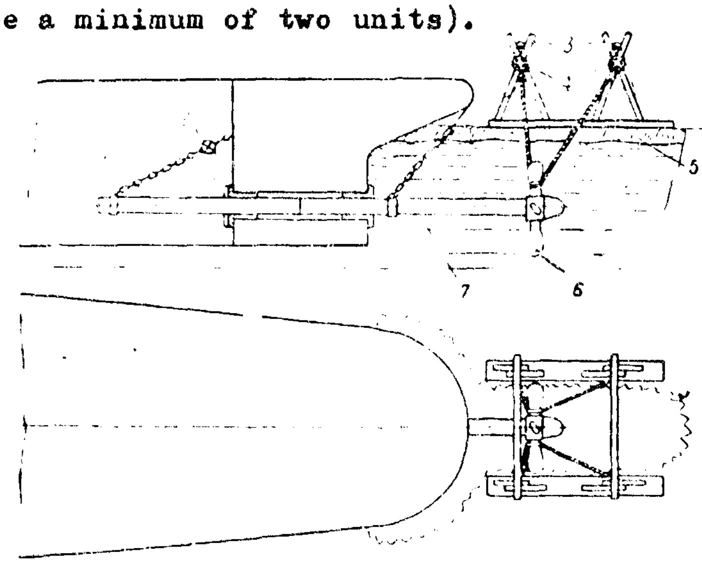


Fig. 27. Pulling the Propeller Shaft into the Water with the Aid of a Dummy Shaft: 1 - dummy shaft; 2, 4 - tackles; 3 - trestles; 5 - ice; 6 - screw propeller; and 7 - propeller shaft.

If equipment is lacking for providing the removal of the shaft from the ship's exterior, the traction force is developed by the block-and-tackle units mounted on the bulkhead (Fig. 27) or by a jack, which rests on the bulkhead or on the base of the intermediate bearing and on the propeller shaft's end. The jack must be placed on a cushion (lining) made of a 3-4 inch board or plank.

When the propeller shaft is completely extruded from the stern tube, the dummy shaft is disconnected from the propeller shaft and the latter is raised to the surface. The dummy shaft is used as a plug and will remain in the stern tube throughout the repair process. In the event of seepage, the space between the deadwood bushing and the dummy shaft is plugged with black oakum or with waste cloths.

If after the removal of the shaft, it is still necessary to press out the deadwood bushing, it is better to utilize the traction method with a cap. In this instance, the cap is placed on a rubber lining on the stud of the gear stuffing box or on the stern tube (Fig. 28).

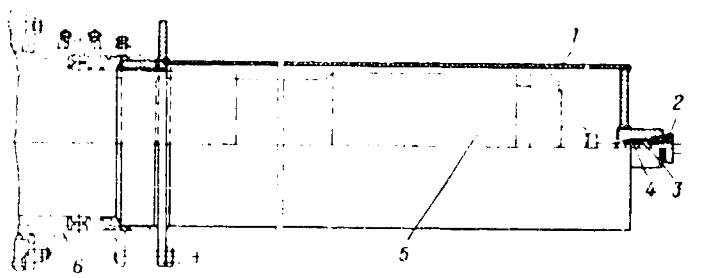


Fig. 28. Cap for Packing the Deadwood Stuffing Box During the Removal of the Propeller Shaft: 1 - frame of cap; 2 - plug of stuffing box; 3 - bushing; 4 - hemp packing, tallow; 5 - propeller shaft; and 6 - deadwood stuffing box.

The cap is made in such a way that it would accomodate the tip of the propeller shaft jutting out of the stern tube. In the case of small dimensions of the propeller shaft, the cap is made blind. During the removal of large shafts, a hole is made in the bottom of the cap with the stuffing box, through which a retaining cable passes. After removal of the shaft, the retaining cable is left in the deadwood and is utilized as a traction (pull) cable during the seating of the shaft.

In certain cases, when the propeller shaft is large and it can not be shifted from its place, through the bottom opening in the cap we insert a pressure bar and we screw it onto the thread in the end of the propeller shaft. With a jack and the pressure bar and also with pullers, the shifting of the shaft is accomplished from over the side.

After the shaft has been moved from its seating, to the end of the pressure bar, we attach the retaining cable. In proportion to the emergence of the shaft into the water, the retaining cable is paid out, the shaft is raised to the surface, and the diver pounds a plug into the deadwood bushing.

In order that the shaft would not be bent during removal, for its support also, on the ships of medium displacement, use is made of a trough (tube) hung from the stern (Fig. 29). For stability, the "trough" has a stiffening (sometimes V-shaped) support with which it rests on the stern overhang.

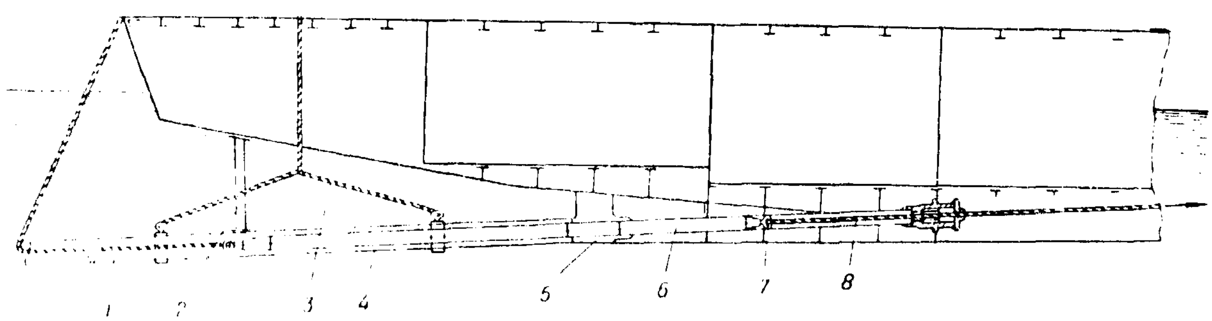


Fig. 29. Removal of Propeller Shaft with the Aid of a "Trough": 1 - pull cable; 2 - bracing stay of trough; 3 - supporting device on block-and tackle units; 4 - trough (tube); 5 - marine propeller strut; 6 - propeller shaft; 7 - clamp; and 8 - retaining cable.

During the removal of shafts from ships having considerable displacement, use is made of a special monorail (Fig. 30). According to a pattern, eye bolts are welded to the sides, and to them on turnbuckles parallel to the axial line of the shaft, the monorail is suspended. On the monorail are mounted 3 or 4 pulleys with turnbuckles (on rollers), on which the propeller shaft is suspended in proportion to its emergence from the deadwood, during which time the pulleys move along the monorail.

For removal of the long shafts, use is also made of the traction (pulling) method, but for the installation of the cap from within the ship, with the assistance of a jack the shaft is advanced about 800 mm into the water. Then for the further removal of the propeller shaft, depending on its length and weight, we utilize a tugboat, the capstan on a floating crane, winch or differential pulleys attached to the bollards of a mooring wall. For this purpose, at a distance selected by calculation, a snatch-block (Fig. 31) is attached, through which the traction cable is passed and fastened to the pulley hook. To avoid the sagging of the shaft, the traction cable is chosen with a length of about 100 m. At emergence of the propeller shaft from the deadwood, it is raised to the surface by a floating crane, and a plug is inserted in the mortar.

Certain designs of the marine shafts can not be removed prior to the extrusion of the shaft bracket bushings. In this case, we pull the fairing and the propeller; the propeller is shifted toward the bow to the extent that its threaded part would emerge from the bushing; the shaft bracket bushing is pressed out and then the removal of the shaft is accomplished.

**Installation of the Propeller Shafts.** In case of installing a propeller shaft from within a ship, it is brought to the stuffing box, on which a metal plug is mounted, and is then rigged in a sling. The diver then checks the airtightness of the deadwood mortar. If water seeps in, the diver pounds a plug in and tightens the calking in the gap.

After this, a metal end cap is applied to the gear stuffing box, with the aid of the block-and-tackle rigs the propeller shaft is clamped in place, and the wooden plug is knocked out with the shaft. The shaft is then blocked and the screw propeller is mounted on it. After this, the assembly of the shaft line is accomplished.

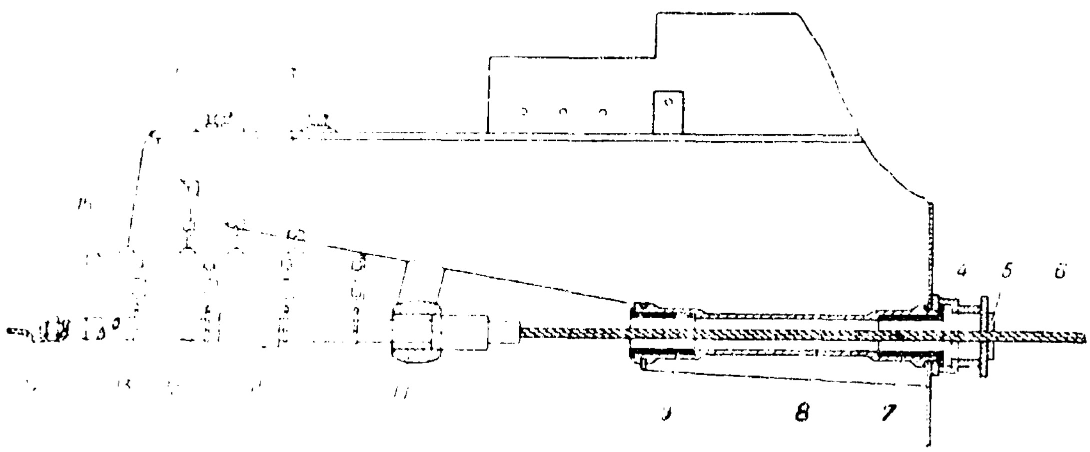


Fig. 30. Pulling a Propeller Shaft into the Water by Traction Method with the Aid of a Monorail: 1 - supporting sling; 2 - bitts; 3 - eye bolts; 4 - cap; 5 - stuffing box of cap; 6 - retaining cable; 7 - bow-type deadwood bushing; 8 - stern tube; 9 - stern-type deadwood bushing; 10 - shaft bracket; 11 - propeller shaft; 12 - pulleys; 13 - lanyards; 14 - traction cable; and 15 - monorail (I-beam).

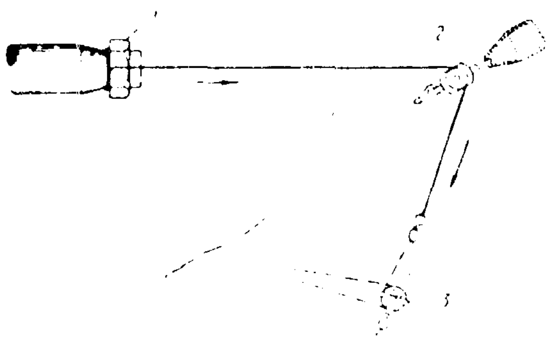

Fig. 31. Diagram Showing Removal of Shaft by Traction Method Using a Shore-Mounted Snatch Block: 1 - propeller shaft with clamping nut; 2 - snatch-block; and 3 - differential pulleys.

We now consider the installation of the propeller shafts from over the side. If there is a dummy shaft in the deadwood, the propeller shaft is installed in the following sequence. The shaft is rigged in a sling and lowered into the water with a floating crane. The diver brings the shaft up to the deadwood and lines it up with the dummy shaft, removes the calking in the gaps and issues the order to turn the dummy shaft from within the ship hull. During the turning, the dummy shaft connects with the propeller shaft. The propeller shaft is then tightened into the deadwood by means of the block-and-tackle. In proportion to the emergence of the dummy shaft from the gear stuffing box, its section are unscrewed and the block-and-tackle is re-rigged.

When the propeller shaft is seated in its place, the dummy shaft is disconnected, the connecting flange is screwed into its place, and the assembly of the shaft's line is accomplished.

During the installation of the propeller shaft when on the gear stuffing box, a cap or metal stopper is mounted, the sequence of the operations changes somewhat. After the delivery of the shaft under the stern and its lining up with the deadwood bushing, the plug is removed, the propeller shaft is inserted and is advanced to the cap or the metal stopper on the gear stuffing box. Then the insertion of the shaft is stopped and the diver calks the gap in the deadwood. The cap or the metal stopper is removed from the stuffing box and the shaft is installed in place. If the stuffing box (oilseal) has been removed, it is also put back in place.

During the installation of the propeller shafts, it is necessary to devote special attention to maintain undamaged the surface of the shaft and the threads on its shank; for this purpose, the shank is covered with cloth, wrapped in canvas and tied.

If the shaft is the side type, it is inserted through the shaft bracket; at this time, caution is exercised since even with the slightest deviation of the shaft to the side, the shaft bracket mounting could be torn loose and the shaft could be bent.

## Section 8. Pressing In and Pressing Out the Deadwood and Shaft Bracket Bushings

In the pressing out and pressing in of the deadwood and shaft bracket bushings, as a precaution against flooding just as in the removal and installation of the propeller shafts, we prepare water drainage equipment and set up a round-the-clock guard.

The extrusion of the deadwood and shaft bracket bushings is performed in connection with the formation of free play and the development of packing or of antifriction lining. Two methods exist for the extrusion of the deadwood and shaft bracket bushings: one involves the use of a special puller and the other is performed with the aid of the propeller shaft.

The first method affords the possibility of extruding both the bow-type as well as the stern-type and shaft bracket bushings. The second method is employed solely for the extrusion of the stern- and shaft bracket-bushings under the condition that the shaft's design permits it to be removed to the inside (of the ship).

First Method. In the extrusion of the bushings by the first method, use is made of various devices consisting of a stay bolt, a shaped (oval) flange and supports--brackets, sleeves, etc. The flange is attached to the bolt on a joint. The universal attachment (Fig.32) is of the most interest.

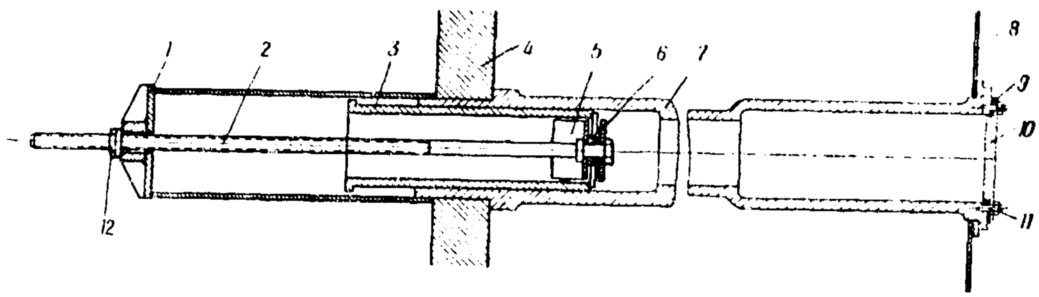


Fig. 32. Extrusion of Stern (Rear) Deadwood Bushing with Universal Attachment: 1 - cap; 2 - coupling bolt; 3 - deadwood bushing; 4 - outer sheathing of ship's hull; 5 - sleeve; 6 - spring-type clamps (clamps activated by springs); 7 - stern tube; 8 - bulkhead; 9 - gasket; 10 - metal stopper; 11 - cotter (stud); and 12-grip nut.

The pressing out of the stern deadwood bushing is conducted as follows: from within the ship hull, we check the seal of the installed metal stopper in the stuffing box or the stern tube. A diver is sent down and the device is delivered to him. By making marks, the diver fixes the bushing's position in the deadwood mortar, knocks out the wooden plug and inserts rod 2 with clamps 6 (Fig. 32).

During the insertion of rod 2 into the deadwood bushing 3, clamps 6 are pressed into the sleeve 5 and the springs are in a contracted position. After the end of rod 2 emerges from bushing 3, the springs drive out clamps 6. From the other side of rod 2, we insert the welded support 1 in the form of a cap, at the bottom of which there is a hole to accomodate the rod. The second end of rod 2 has a thread for holding the stop (pressure) nut 12.

If there is not a chance of making a universal device with the spring clamps, one then makes a solid oval flange with an elongated opening for the passage of the bolt. The flange, seated freely on the bolt, occupies an inclined position and passes through the bushing and, at reverse movement of the bolt, it engages the end of the deadwood bushing. The bolt head is made solid and its dimensions exceed the diameter of the flange's central hole.

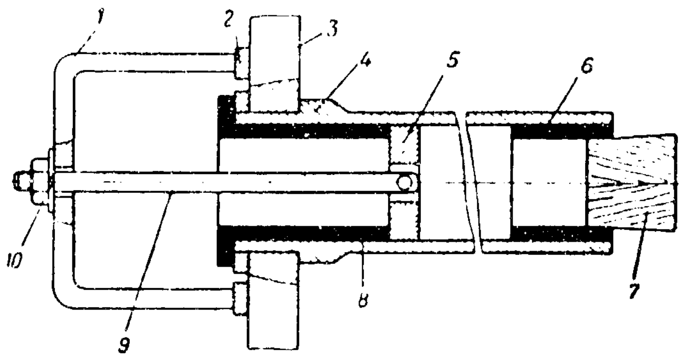


Fig. 33. Device for Pressing Out the Deadwood Sleeves (Bushings) with Forming Flange on a Joint:
1 - clamp; 2 - cushion; 3 - sheathing; 4 - stern tube; 5 - forming flange; 6 - bow-type deadwood bushing; 7 - wooden plug; 8 - stern-type deadwood bushing; 9 - coupling bolt; and 10- stop nut.

Bolt 9 (Fig. 33) can be fastened in flange 5 by a pin (hinge joint). The flange is so arranged that in its passage through the deadwood sleeve, it is beneath the bolt's shank. On bolt 9, we mount the clamp (support) 1, plus a washer, and we screw on the stop nut 10. A wooden cushion is placed under the support.

For pressing out the sleeve, we turn the stop nut, at first by hand, and then the sleeve's extrusion is conducted by means of a wrench fitted with a long handle, with the aid of a rope lowered from the deck. When the sleeve's flange has separated slightly from the stern tube, the diver rigs it with a sling fed from the upper deck. Then the diver resets the wrench and sees to the emergence of the sleeve from the deadwood's mortar.

The pressing-out device is chosen according to the sleeve's dimensions. The bolt should have more than two lengths of the sleeve, while the clamp or cap should have such dimensions that the sleeve could be completely extruded.

The attachments (devices) equipped with clamps are ordinarily utilized for pressing out the deadwood sleeves of small dimensions. If the sleeve is large (with a diameter of 400 mm and more), we resort to the universal (general-purpose) device equipped with clamps. If in length the sleeve turns out to be slightly larger than the clamp's height, during the assembly of the device, we place beneath the clamp a cushion, or pads are welded to the sheathing in the support points. /53

After it has come out of the stern tube, the sleeve is placed on a scaffold, the device is removed from it, the sleeve is re-slung and hauled upward.

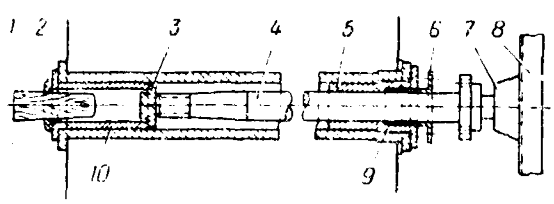


Fig. 34. Extrusion of Stern Deadwood Sleeve with Use of Propeller Shaft: 1 - wooden plug; 2 - resinous packing material or oakum; 3 - forming flange; 4 - propeller shaft; 5 - bow deadwood sleeve; 6 - deadwood stuffing box; 7 - jack; 8 - support channel bar; 9 - gasket packing; and 10 - stern deadwood sleeve (bushing).

The bow deadwood sleeve is extruded in an analogous manner.

The second method of extruding the stern and shaft bracket sleeves with the aid of the propeller shaft (Fig. 34) is accomplished in the following order. After the removal of the propeller, the propeller shaft 4 is moved by block-and-tackle into the interior of the ship's hull. As soon as it has separated from the mortar by 200-300 mm, the diver pounds the wooden plug 1 into the stern tube, and the shaft is completely removed. Into the stern tube from within the hull, we insert the parting flange 3 with recesses for resting the sleeve onto the end. The propeller shaft is inserted into the stern tube and rests against the flange.

In the afterpeak, across the ship we place the channel bar 8, resting by its ends on the side branches of the bulkheads, while between the channel bar and the propeller shaft's connecting flange, we set up the jack 7. By use of the jack, the propeller shaft is gradually moved into the stern tube while the deadwood sleeve is extruded. /54

After the extrusion of the stern sleeve, the shaft is advanced slightly into the ship, and the diver installs the wooden plug. The propeller shaft is removed and from within the hull, a metal stopper is placed on the stern tube. The shaft can also be left in the stern tube but this is not desirable since water seepage into the ship hull is possible.

During the installation of the parting flange and the work in the stern tube, the diver observes for and provides the tightness (hermetic state) of the stopper.

In case of the extrusion of the bow sleeve, the metal stopper is placed on the stuffing box after the completion of the entire range of tasks.

For extruding the shaft bracket sleeve, the propeller shaft is moved with block-and-tackle to the interior of the deadwood until its shank protrudes from the shaft bracket sleeve and there is adequate space for installing the support flange. The shaft is then moved into the stern, rests with its end on the center of the installed flange, and by means of the force developed by a jack from inside the ship hull, the shaft bracket sleeve is pressed out (extruded).

If only the shaft bracket sleeves are extruded, the propeller shaft is brought to its normal position, while the gap is calked with black oakum or with loose strands of plant fiber.

The pressing-in of the deadwood and shaft bracket sleeves is conducted by two methods: with the aid of a rod and flange (universal for all types of sleeves) and with the use of a jack (only for the bow-type sleeves).

The installation of the bow deadwood sleeves is performed in the following sequence. Before the start of the operations, the diver checks the tightness of the installed external stopper or plug. The metal stopper is removed from the bulkhead stuffing box, and the sleeve is inserted into the deadwood tube roughly in accordance with the marks.

On the sleeve's front end (Fig. 35), a flange is mounted and having a recess, while athwart the ship, we place a support channel bar; a jack is placed between them. With use of the jack, the sleeve is forced into the deadwood tube; after this, the jack and the channel bar are taken away, while a metal stopper on a lining is installed on the tube.

The pressing-in of the stern deadwood sleeves (Fig. 36) with /55 the aid of a rod and flange is conducted as follows. On the bow end of the stern tube, we install on a rubber lining the flange 3 with a central hole. Through the flange's central opening, we insert rod 6 with washer 4 and nut 5. On one end, the rod's threaded portion is greater than the length of the sleeve which is being pressed in, while at the other end, it is 100-150 mm long. The rod is passed through the stern tube until it is stopped by the wooden plug.

A diver then descends; he is sent the deadwood sleeve rigged on a sling, as well as the parts of the attachment for the pressing-in work: the stopper, rubber lining and nuts. The diver moves the sleeve toward the stern tube and at his command, from inside the hull the workers use the rod to ~~knock the~~ plug out and to bring the rod to its position.

The diver passes the rod through the deadwood sleeve, prepared and suspended on the slings, places the spacer and metal stopper on the threaded part of the rod, and screws on nut 9 with a locknut. He then lines up the sleeve with the stern tube, orienting it according to the marks (graduation lines), and develops a tension by tightening the nuts. He then issues a command for the pressing-in of the sleeve. In this case, the sleeve is pressed in by the marine repairmen from within the ship hull by turning nut 5, while the diver monitors the progress of the work; in case the sleeve should get out of line, he straightens it.

However, if the sleeve can not be pressed from inside, the rod is inserted into the stern tube, by the end with the long thread. The diver presses in a small sleeve by manually turning the pressure (clamping) nut with a wrench. If the sleeve happens to be large, after assembling the device and developing tension, the diver turns the pressure nut with a long-handled wrench, and the insertion of the sleeve is accomplished with the aid of a sling lowered from the deck, where the ship crew or the ship repair enterprise workers stretch the cable by mechanical means or by hand. The diver resets the wrench when it reaches the extreme position, monitors the progress of the operations and sees to the proper centering of the sleeve; if misalignments develop, he rectifies them. After the sleeve has entered the stern tube for 2/3 of its length and assuming that conditions permit it, for speeding up the pressing-in process, the pressure nut is also turned from inside the hull. /56

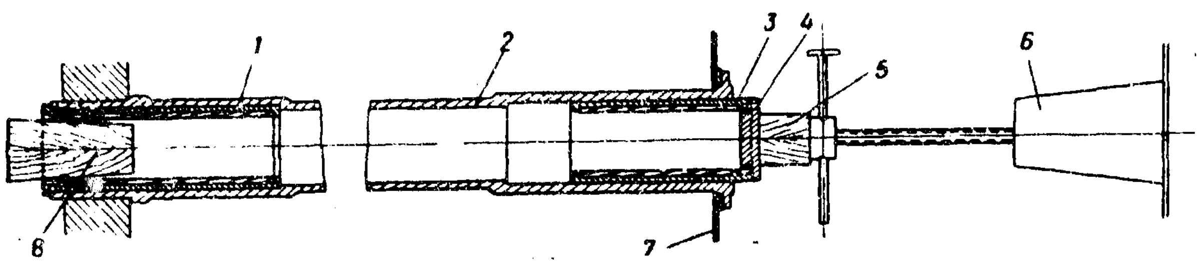


Fig. 35. Pressing in the Bow Deadwood Sleeve with a Jack:
1 - stern deadwood sleeve; 2 - stern tube; 3 - bow deadwood sleeve;
4 - forming flange; 5 - cushion; 6 - jack; 7 - bulkhead; & 8 - plug.

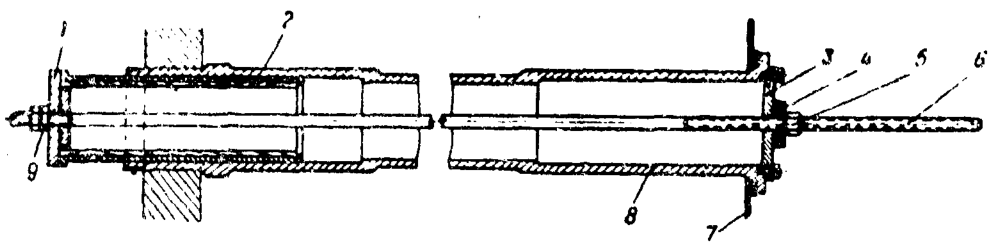


Fig. 36. Pressing in the Stern Deadwood Sleeve with a Flange-Rigged Bar from Within the Ship's Hull: 1 - metal closer (flange); 2 - stern deadwood sleeve; 3 - flange with opening; 4 - washers; 5 - pressure nut; 6 - rod; 7 - bulkhead; 8 - stern tube; 9 - nut and locknut.

When the sleeve has reached its position, the diver fastens /57
its flange to the deadwood's mortar with standard pins, then turns off the nut and removes the device's stopper. The rod is tightened inside the ship while the diver pounds a wooden plug into the sleeve.

After this, the device's rod and flange are removed and the water which has gotten into the stern tube is pumped out. The further actions are contingent on the actual conditions: whether to continue the work on assembling the shaft line, or to install a blind metal closer on the bulkhead stuffing box.

The shaft bracket sleeves are pressed in with a similar device of smaller dimensions. In this case, all the tasks are performed by the diver with rigging furnished from the upper deck of the ship.

The replacement of the packing in the deadwood stuffing box can be accomplished while the ship is afloat. For this purpose, we disconnect the propeller shaft and remove the connecting flange. If a protective jacket is placed between the propeller hub and the mortar, the diver first removes this jacket. If it is inconvenient to gain access to the deadwood's mortar from the water side, with block-and-tackle the shaft is moved by 200-300 mm into the stern.

The diver then calks the space between the shaft and the deadwood sleeve with black oakum. The stuffing box is removed, the packing is changed; the stuffing box is then installed in place and fastened with standard pins or bolts. The diver then removes the calking, the propeller shaft is dragged into place, and the protective lining (jacket) is placed on its journal.

If the shaft has not been shifted and lacks a protective lining, after removal of the calking from the gap in the deadwood, the diver climbs out of the water.

## Section 9. Laying Out the Axial Line of a Shaft While Afloat

The work involved in laying out a shaft's axial line calls for high skill on the part of the performers and great care since it is necessary to superimpose the actual line of the shaft with a theoretical one according to which the shafting is assembled.

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From the standpoint of the least deviations from the theoretical line of the shaft, it is best to assemble the shafting when the ship (vessel) is afloat when its weight is distributed uniformly over the hull and is supported by the water.

Proceeding from these concepts, we recommend the laying out of the shaft's axial line while the ship is afloat, not only during the repair but also during the construction of the ship.

The laying out of the shaft's axial line while afloat is achieved either with extending a wire or with a light beam.

**Laying Out the Axial Line with a Drawn String.** In the performance of this operation, for the base we assume the seating strip of the shaft bracket or of the deadwood's mortar, under the stipulation that their geometric dimensions are retained.

The laying out of the axial line is conducted from the stern to the bow of the ship. As the stern point for the axial line, we adopt the center of the stern boring of the deadwood or of the shaft bracket, and as the bow point, we adopt the center of the deadwood's bow boring. The laying out of the shaft's axial line is conducted after the removal of the propeller shaft and the extrusion of the deadwood sleeves, when the main engine is in place. If the engine has been pulled, in place of it in the double-bottom space in the region of the engine bays, ballast (water) is taken on in a quantity roughly equal to the weight of the engine which has been pulled.

In the presence of a shaft bracket (Fig.37), for the laying out of the axial line with a string, the packing filler connecting the deadwood's mortar with the shaft bracket is installed.

The covering sheath consists of tube 6, flange 7 and of the stuffing box filler 5. Before the placement of the sheath, we check the tightness of the metal closer on the deadwood within the ship. The covering sheath is then sent to the diver on slings. The diver knocks out the wooden plug and installs the flange first, followed by the covering sheath, which is tightly calked from both ends of the stuffing box filler 5. The covering sheath is installed after the mounting of the centering flange.

The centering flange 2, into the center of which is inserted the micrometer screw 3, is installed from the outside of the shaft bracket. The flange has the sealing strap 4 and the stuffing box filler 1. The seating (fitting) of the centering flange onto the stern seating strip is close (the clearance is not more than 0.18 mm). The gap is checked /59
with a feeler gage from the bow end of the shaft bracket.

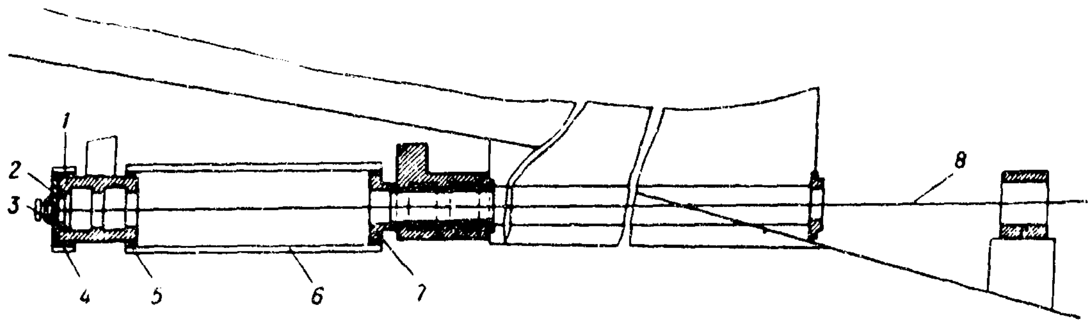


Fig. 37. Laying Out a Shaft's Axial Line with a String in the Presence of a Shaft Bracket: 1 - packing; 2 - centering flange; 3 - propeller; 4 - sealing strap; 5 - packing; 6 - sealing jacket; 7 -flange; and 8 - string.

The centering flange has a slight conicity on the exterior belt for precise fitting to the seating strip. To the micrometer screw, we attach string 8 and it is stretched within the ship's hull.

The entire operation on laying out the axial line is conducted by the conventional methods used by the metal fitters (for more details, see below: "Laying Out of a Shaft's Axial Line with a Light Beam").

**Laying Out of an Axial Line with a Light Beam.** For the accomplishment of this work, we utilize a special illuminating device (Fig. 38). The illuminating lamp consists of the sealed frame 14 with cover 1; the frame contains chamber 15 with a light source, i.e. the hand-type battery-powered lantern (fastened by clamp 11) or with the lamp 20 using 12 volts from the onboard network.

Chamber 15 is rigidly connected with the hinged joint 4, having an opening for the passage of the light beam. Joint 4 is fastened in /61
flange 6 by the pressure flange 12, having the illuminator 9 and the coupling nut 7. By means of the two mutually-perpendicular screws 2, extending to the outside, through the support bulbs 3, we can alter the direction of the light beam by varying the position of chamber 15. The two springs, 10, provide the chamber with a stable position in space.

Variant I

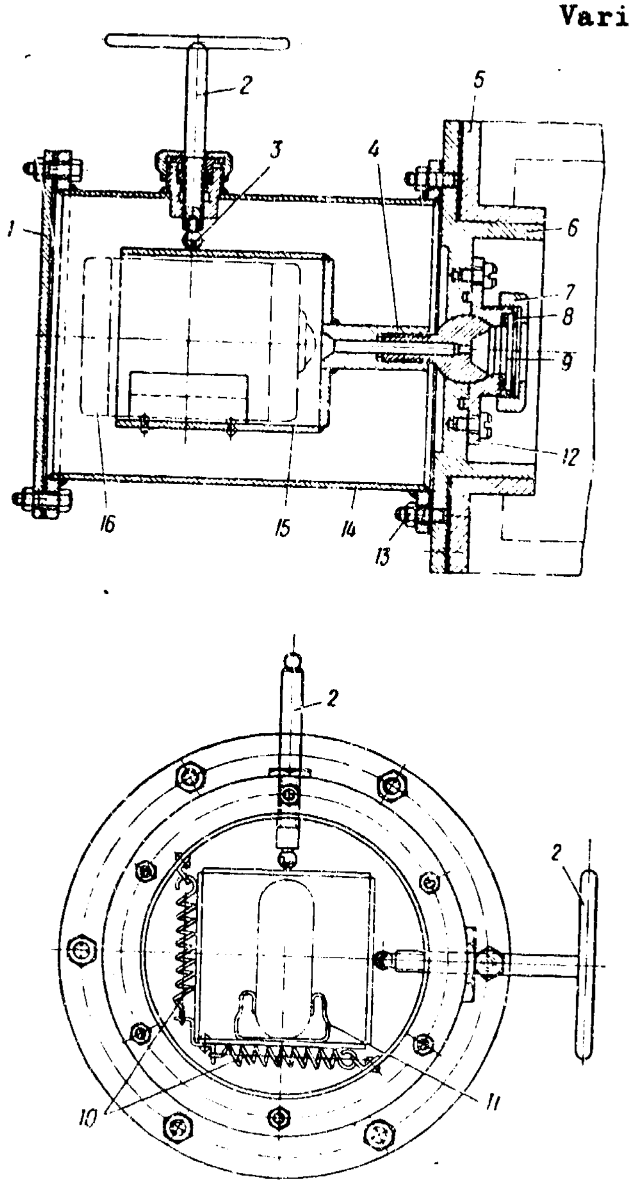


Fig. 38 (see caption, next page)

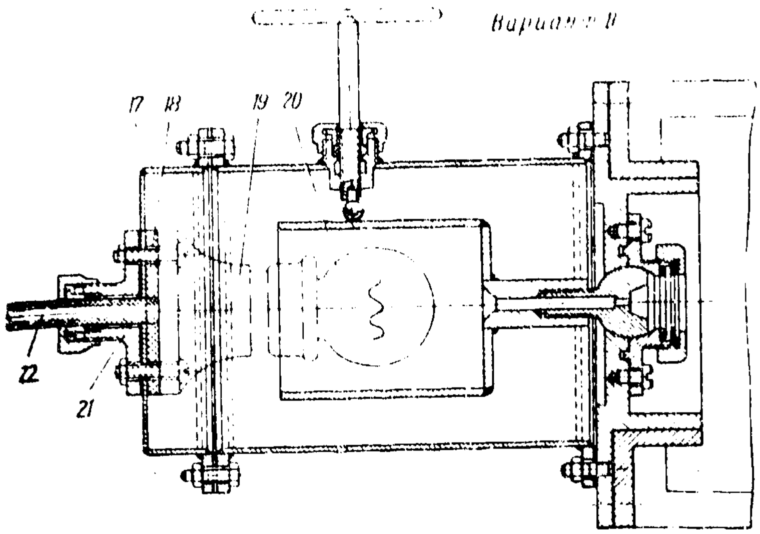


Fig. 38. Illuminating Device for Laying Out a Shaft's Axial Line with a Light Beam: 1 - cover; 2 - adjusting screws; 3 - support bulbs; 4 - joint; 5 - removable flange; 6 - flange of joint; 7 - coupling nut; 8 - mantle ring; 9 - illuminator; 10 - springs; 11 - clamp; 12 - pressure flange; 13 - mounting pins; 14 - frame of illuminating device; 15 - light chamber; 16 - battery lamp; 17 - covering under electric bulb; 18 - ebonite strip; 19 - socket; 20 - electric bulb; 21 - fitting; and 22 - electric cable.

By pins 13, frame 14 is fastened to the centering removable flange which is prepared in place in accordance with the outer strip of the flange to the jointed connection of illuminator 6. The fitting between flanges 5 and 6 should be the slide fit according to class II of accuracy with a clearance of not more than 0.23 mm.

In the utilization of the electric power from the network, to the frame of the illuminator, there is mounted on a lining the forming cover 17 provided with the ebonite strip 18, socket 19 and fitting 21, with a packing hole for the electric cable 22. /62

The use of the electric bulb 20 fed from the network is recommended on the ships having a long stern tube. After the installation of the sealing jacket and of the illuminating device, we remove from the stern tube the bow cap, pump out the water which has gotten into the deadwood and we lay out the shaft's axial line.

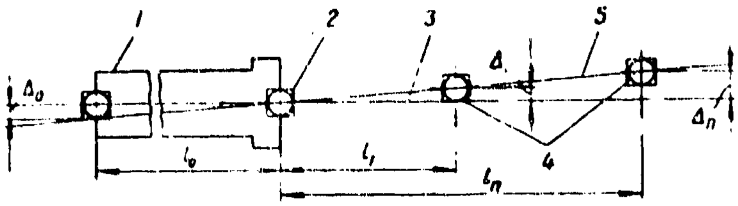


Fig. 39. System of Installing Targets for Laying Out a Light Line: 1 - deadwood; 2 - zero target; 3 - geometric axis of the deadwood; 4 - intermediate target; 5 - optical axis (light beam); $\Delta_0$, $\Delta_n$ = ordinates of deviation of light axis's center (of the light beam) from the deadwood's geometric axis (in a vertical plane); $l_0$ = the length of deadwood in m; $l_1$ = distance between the zero and intermediate targets in m; and $l_n$ = length of string in m, from zero to last target.

For this purpose, the metal fitters install the zero target 2 (Fig. 39) in the bow center of the deadwood's mortar and align the optical axis 5 of the lamp with the center of the zero target 2. Then in sequence in a direction from the ship's stern to its bow, we set up the intermediate targets 4 and with the micrometer screws available on the targets, we align their centers with the optical axis of the lamp (with the light beam) 5.

After this, the string (line) is extended across the targets; this line is fastened in a stretched position. Then a measurement is made of the position of the foundations relative to the line, a sketch is drawn of their arrangement and we establish the displacement of the shaft's axial line in the horizontal and vertical planes relative to the deadwood's geometric axis.

On the basis of the measurements made according to the appropriate formulas, we find the deviations in the luminous axis of the shaft's line from the geometric axis of the deadwood's mortar, and we compile a table of the displacements. In conformity with the data developed, we perform the correction of the established bases (or we determine the position of those being re-established) and of the bearings (supports) of the shafting line.

At the instruction of the metal fitters, the diver should turn the adjustment screws of the lamp and by the same token, the optical axis (the light beam) is aligned with the center of the zero target, 2.

Upon the completion of the tasks in the laying out of the axial line, onto the deadwood's mortar we once again place the bow metal closer, while the illuminating lamp and the sealing jacket are disassembled. From the outside, we place a stopper on the stern tube, or else drive in a wooden plug.

## Section 10. Tools and Instruments for the Underwater Repair of the Propeller System

The tools and most of the equipment used for repair of the propeller system under water are the same as used during the repair of ships in dock.

Under the conditions of underwater ship repair, to facilitate the divers' work, use is made of various special wrenches, e.g. the ratchet wrench (Fig.40) with a detachable head for turning off the pressure nut to the screw propeller, the support bolts in the mechanical pullers, the nuts and bolts in the attachments for the extrusion and pressing in of the deadwood and shaft bracket sleeves, and so forth.

The detachable head is mounted on bolts in the ratchet and permits the use of the same wrench for nuts and bolts of different sizes (S = 41 - 110 mm). The tightening and loosening of the nuts are conducted by rocking the handle. To increase the handle's length, it has a blind hole into which a pipe can be inserted.

For loosening the nuts with a square head and for cutting threads with taps, use is made of similar ratchet wrenches of other dimensions. For the round nuts and streamlined cap nuts not having flat surfaces and also for shafting nuts with a diameter ranging from 85-220 mm, use is made of the crescent wrenches (Fig. 41).

For the very same purpose, we also utilize the double-ended wrench. For the large pressure nuts, we use special heavy-duty adjustable and open-ended wrenches.

For drilling out the pins and plugs on the fairings of the screw propeller, we utilize a special attachment (Fig. 42).

Frame 1 of the device is fastened by means of the centering bolts 8 to the fairing 2 with the consideration that the drill 3 would be positioned coaxially with the pin which was being drilled out.

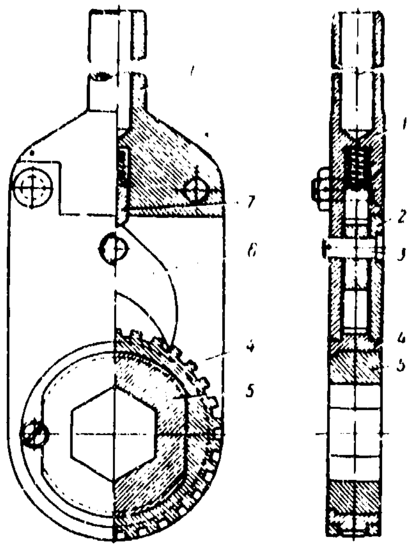


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Fig. 40. Ratchet Wrench with Detachable Head for Nuts Ranging from S = 41 - 110 mm in Size: 1 - lever (handle); 2 - jaws; 3 - pawl axis; 4 - ratchet; 5 - detachable head; 6 - pawl; and 7 - stop.

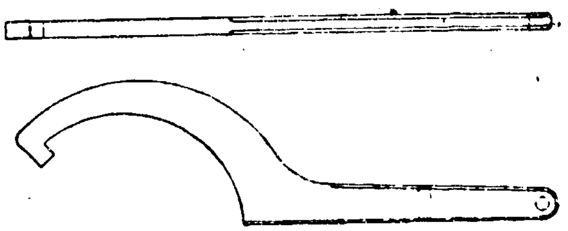

Fig. 41. Crescent Wrench for Removing Round Nuts and Streamlined Cap Nuts.

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The center of the drill rests on cleat 5, which is fastened by pressure nuts 6 on pins 7 of the guide blocks 4.

In this manner, the diver is relieved of the need to press on the machine during the drilling; he can monitor the progress, turn the handle of the machine and thereby he can assure the normal feed of the drill. The device has been tested in the practice and justified itself completely.

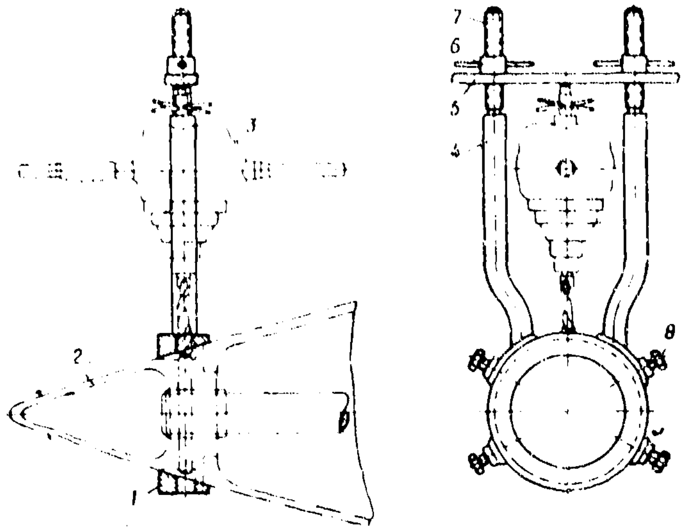


Fig. 42. Device for Drilling Out the Stops and Pins in the Screw Propeller's Fairing: 1 - frame; 2 - fairing; 3 - drill; 4 - guide blocks; 5 - pressure cleat (strip); 6 - pressure nuts; 7 - pins; and 8 - centering bolts.

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## CHAPTER 3

## REPAIR OF RUDDER DEVICES

The repair of the submerged part of a marine rudder unit is conducted in case of the wear of the rudder stock in the points of its passage through the rudder trunk when twisted and in the case of the formation of cracks in it; in case of the wear of the bushings, collar and bearing; in case of corrosion of the pins and sheathing of the rudder fin. It is also possible to find breakages and missing parts of the rudders, discrepancy in the actual position of the rudder fin vis-à-vis the readings of the rudder indicator.

### Section 11. Elimination of Rudder Fin Deviation from Diametral Plane

For checking out the position of the rudder fin, the diver is sent down and he obsrves the positioning of the rudder on both sides. In the case of detecting a deviation, the indicator needle is slackened slightly, the rudder is reset to one of the extreme positions and the needle is set in position. The rudder is then moved to the other side in its extreme position. In this connection, the needle should indicate the maximal conversion angle.

If coincidence does not occur, the adjustment of the rudder is repeated several times from side to side, the error is determined and based on the arithmetic mean (figured on the basis of the rudder indicator at the top), the indicator needle is set. When the rudder fin is in the ship's diametral plane, the indicator should occupy the zero position.

### Section 12. Repairing Rudders Without Hoisting Them to the Surface /67

If the damages are minor, the rudder is not raised to the surface and the diver fixes them on the spot. The cracks on the rudder stock and fin are scraped and repaired by electric welding. The worn-out rudder pintles are replaced; for this purpose, the rudder is raised with a block-and-tackle (Fig.43), suspended on a gantry, prior to the separation of the pintles from the collar, and is fastened with ropes.

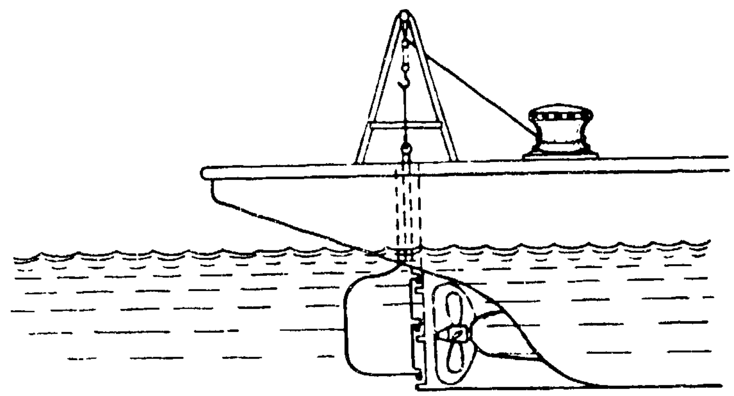

Fig. 43. Suspension of Vertical Rudder for Repair (on the Spot) of Minor Damages.

The diver removes the cotterkey and releases the nut, the damaged pintle is knocked out with a punch, and a new one is installed. If it is not possible to knock out the old pintle, it is cut off, a new piece is welded on, the joint is cleaned and the reinforcement of the joint is filed down to size.

For repairing the gudgeons, the rudder is removed from the rudder trunk and is placed on the sea floor or a scaffold, the worn gudgeon is removed, e.g. by oxy-electric cutting, and the repair is made. A new gudgeon is made in the shop or on the ship and is installed on the spot. The centering of the gudgeon is performed with a line run through the helmport (Fig.44). Instead of centering with a line, one can utilize a tube-conductor. According to the dimension of the rudderhead, the tube is passed through the remaining gudgeons, the new gudgeon is mounted on the tube, moved into position, and /68 the tube is then removed. The application of the tube-conductor excludes any possible misalignment of the gudgeon.

The repair of the sheathing to the rudder fin (if the unit is undamaged) is conducted under water with the application of patches prepared according to a pattern.

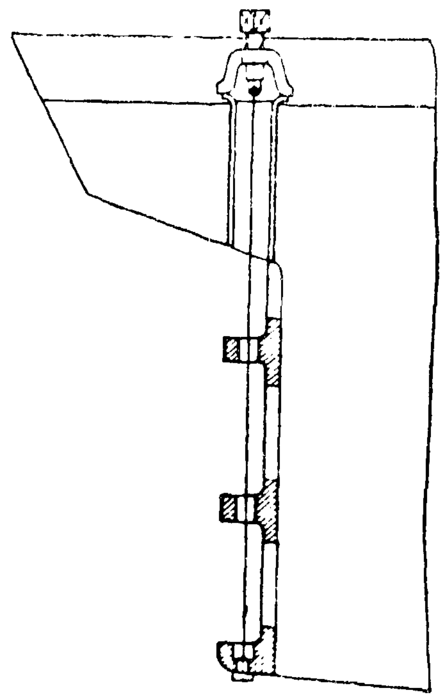

Fig. 44. Centering the Gudgeons of Vertical Rudder with Line.

The sheathing of the rudder fin is thin, therefore the welding on of the patches is conducted carefully, with thin 3-4 mm electrodes with low current force.

Each patch should be so placed that if possible its edges would coincide with the unit of the rudder fin.

If the ship is not loaded and part of the rudder fin protrudes above water, the patches are welded on without removing the rudder from the gudgeons and without suspending it on rope rigging.

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After the welding of the patches in the sheathing, the rudder fins are drilled at the top and bottom, making one hole in each place with a diameter of 8-10 mm (the upper hole in the part of the fin which protrudes from the water).

Then through a hose to the top hole, we supply compressed air, and the water which has gotten into the rudder fin cavity is forced out.

After removal of the water, we install metal caps on rubber linings in the drilled holes: first on the bottom hole, then on the top.

The cap is installed on the lower hole without disconnecting the hose, and is done under pressure (slightly exceeding the hydrostatic) of compressed air. Although this procedure is laborious, it assures the prevention of water seepage into the rudder fin cavity.

### Section 13. Raising the Rudders to the Surface

If the rudder has sustained extensive damages, it is hoisted up. In this instance, if the design so permits, the rudderhead and fin are raised separately.

The hoisting of a unitized rudder is conducted in the following sequence: the rudder chain is disconnected, the key is removed, as well as the plate tiller or the rudder sector with the head, and the tiller (sector) is shifted from the rudderhead by means of the conventional wedge method. For facilitating the disassembly from the rudderhead, the tiller or rudder sector is heated with a gas burner or a blow torch. The stuffing box is then disassembled and an eye bolt is screwed into the end of the rudderhead. The rudderhead is slung by the eye bolt with block-and-tackle, suspended on a gantry positioned on the upper deck (Fig.45).

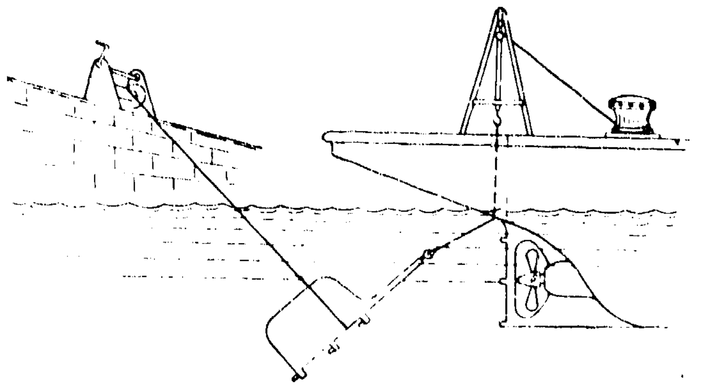

Fig. 45. Pulling a Vertical Rudder from Under the Stern Overhang.

After this, a diver is lowered and if the depth is great under the keel, a scaffold is set up. From the next ship or from shore, depending on conditions, the diver is provided with an auxiliary rope, with which he rigs (slings) the rudder, then removes the keys, removes or cuts off the nuts and knocks out the pins.

If the design of the rudder's structure permits it to be raised without knocking out the pins (e.g. in the case of a hinged system), the diver limits himself to the removal of the nuts and issues the order for raising the rudder to the surface.

The hoisting of the rudder is performed under the supervision of the diver. At first the rudder is raised vertically prior to the emergence of the heel from the thrust bearing; the hoisting is then /70 stopped and the rudder is drawn to one side with the aid of a winch mounted on shore or on another ship. The main cable is simultaneously slacked away. The pulled rudder is lowered to the ground or onto a scaffold.

The diver removes the eye bolt screwed into the rudderhead end and re-rigs the rudder. If the rudder can not be accomodated on a scaffold, over the side from the upper deck, an extra line is run; with this, the diver lashes the rudder at the point of the rudderhead's connection with the fin. At relaxation of the main cable with the block-and-tackle, the rudder's weight is transferred to the auxiliary line. After this, the main cable is removed and the rudder is hoisted to the surface.

## Section 14. Repairing the Gudgeon Bushings and the Rudder Thrust Bearing

The worn-out bushings are extruded with a puller, repaired and pressed back into place, or else new ones are assembled. The puller is used according to a design analogous to that described above, in conformity with the gudgeons' dimensions.

For removing the bushing from the bearing seating, the diver drives a wooden arbor (Fig. 46) into the bushing and unscrews the bushing plug. Onto the collar, a clamp is then mounted, through use of a drill. With a drill bit having a diameter equalling the thickness of the bushing's walls, we drill the bushing at 2 or 3 points over its entire length. The bushing cut into pieces in this manner is removed from the bearing seating. At the same time, we remove the wooden arbor and the lens (if one is present).

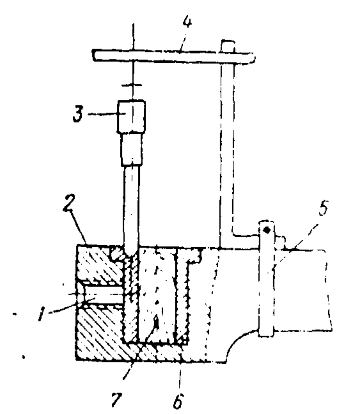


Fig. 46. Drilling Out the Bearing Bushing of Vertical Rudder: 1 - hole for plug; 2 - thrust bearing; 3 - drill; 4 - clamp; 5 - collar; 6 - bushing; and 7-wooden arbor.

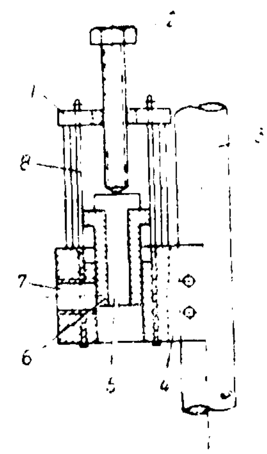


Fig. 47. Pressing in the Gudgeon Bushing of Vertical Rudder: 1 - release strip; 2-pressure bolt; 3 - rudderhead; 4-gudgeon; 5 - arbor; 6-bushing; 7-hole for plug; and 8- hooks.

The bushings of the rudder gudgeon or thrust bearing are pressed in by means of a special pressurizing device (Fig.47). The diver places bushing 6 in the socket, mounts a device on the gudgeon of rudderhead 3; this device (attachment) consists of arbor 5, hooks 8, transverse strip 1 with a hole cut in the middle, and of pressure bolt 2. After the hub (bushing) is pressed in, the plug is installed, the attachment is disconnected and released for hoisting up.

## Section 15. Installation of Rudders on the Spot

The installation of a one-piece rudder on the spot after repair is conducted in the following sequence. The rudder with a lug screwed into the rudderhead's end is lowered on a rope to the diver. A second /72
rope is lowered from the upper deck through the rudder trunk (helmport), the diver lashes it by the eye bolt , and slackens the first rope. In addition, he rigs a line from an auxiliary winch set up on shore.

The operations are conducted in the same way as in the pulling of the rudder from under the stern (Fig.45), but in this instance, the line from the main block-and-tackle on the upper deck is tightened, while the line from the auxiliary winch is eased off. The diver regulates the movement and hoisting of the rudder, directing it in such a way that the rudderhead would enter the helmport and would not damage it.

After the rudderhead is moved, the rudderhead is hung vertically and the auxiliary line is slackened. The rudder heel is then brought to the thrust bearing and the rudder is lowered. As soon as the heel is in place and the gudgeons line up, the pins are inserted, secured with nuts, and the cotterkeys are assembled. If the pins had not been knocked out, then enter the gudgeons simultaneously with the seating of the rudder heel.

At the top, from the rudderhead end, the eye bolt is removed, the stuffing box is assembled, and the rudder sector or the tiller are installed in place.

## Section 16. Repair of Horizontal Rudders

The repair of horizontal rudders while afloat, other than the minor damages which are repaired similarly with the methods already described, reduces to the disassembly of the rudders for hoisting to the surface and the subsequent assembly after their repair in shop. A design feature of the horizontal rudders is the presence in the rudderhead of two cones with cut shanks; therefore the removal of the rudders is similar to the removal of the screw propellers.

First we remove the cotterkeys, pull the fairings, pressure nuts, and then we disassemble the rudder. The tapered keys are knocked out with a drift and a sledgehammer; the rudder fin is removed with wedges or by means of mechanical pullers.

In the installation, the horizontal rudder fin is moved onto the shaft's cone and is finally adjusted into place by turning the pressure nut.

# CHAPTER 4

# REPAIR AND INSTALLATION OF NEW SIDE FITTINGS (MOUNTINGS)

In the practice of underwater ship repair, we often encounter tasks involving the repair and installation of new side and bottom fittings, and also the replacement of the protective strips and rings.

## Section 17. Replacing the Gratings of Side Mountings

Before starting the operations, the diver checks the design of the grating's fastening and the sizes of the bolts (or nuts), then rigs the grating with a hemp rope lowered from the deck.

The nuts are removed with a socket or special wrench with a curved handle. The nuts usually have a right-hand thread; therefore, they are removed by turning the wrench to the left. After the removal of the grating, the diver carefully cleans the hull sheathing at the contact points of the grating and the shaft with the exterior surface. In the grating's installation, for its close fit over the entire perimeter, the nuts are turned alternately, with a gradual tightening.

## Section 18. Cleaning the Kingstons and Other Side Mountings

For the preventive maintenance cleaning of the kingston, after the removal of the grating, the diver places in the same holes a metal cap with a rubber lining; he then opens the kingston valve from inside the ship. If the round grating is welded into the hull, an umbrella-shaped cap is installed above it (Fig. 48).

Such plugs are often mounted on the side fittings of ships during a winter layover.

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If the grating is rectangular in form, in place of the plug we install a box-caisson on under-keel slings, which during the opening of the fitting presses against the ship hull owing to the difference in the pressures.

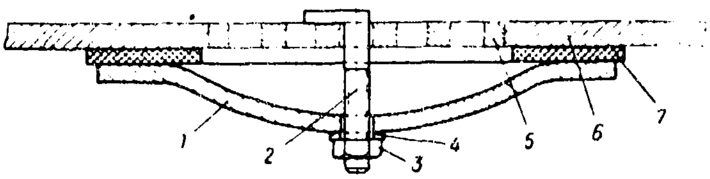


Fig. 48. Metal Umbrella-Shaped Closer for Round Side Openings: 1 - flange (closer); 2 - forming bolt; 3 - nut; 4 - washer; 5 - protective grating of side opening; 6 - ship sheathing; and 7 - rubber lining (padding).

## Section 19. Replacing the Pins of the Side Mountings

If the pins have been eaten by corrosion or the thread on them is stripped, they are replaced. Usually, however, the pins are so covered with rust (jammed) that they have to be drilled out. If the pin has not been broken, one should try to turn it out.

For the extraction of the pins with a diameter up to 22 mm, we use a special wrench equipped with a cam (Figures 49 and 50).

The wrench is placed on pin 2 with cam 3 set in the extreme position (see Fig. 50a). If the pin has a right-hand thread, the cam must be turned from left to right, i.e. in a clockwise direction, and vice versa. The cam 3 is turned around its own axis 4 and presses pin 2 closely against the inner walls of hull 1 and "wedges it up" (see Fig. 50b).

During the unscrewing of pin 2 with the wrench, owing to friction cam 3 will press even more strongly on pin 2, forcing it against the walls of hull 1, and will provide the transfer of the torque to the pin (see Fig. 50b) and turn it out of the socket.

If no special wrench is available, the diver turns two nuts as far as they will go on the pin, pressing their ends close gogether; he then applies a standard wrench to the lower nut (in contact with the sheathing) and turns the pin out.

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In the installation of new pins, one can also utilize two nuts, but it is necessary to apply the wrench to the top nut.

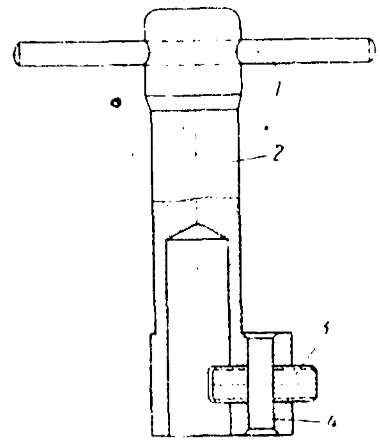


Fig. 49. Cam (Eccentric) Wrench: 1 - handle; 2 - frame; 3-cam; and 4 - cam axis.

For removing the small pins, use is also made of a socket wrench with removable socket (Fig.51).

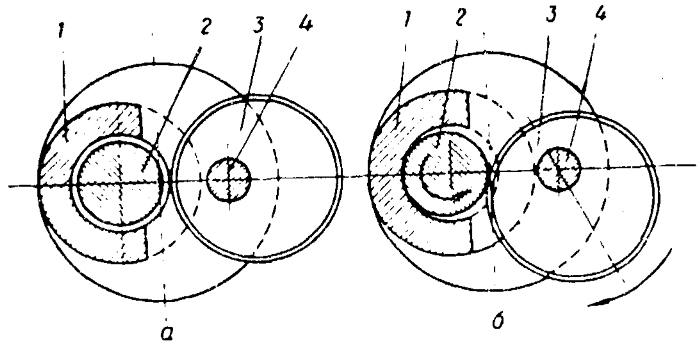


Fig. 50. Operating System of Cam Wrench: a - position of cam during placement of wrench on pin; b - position of cam during removal of pin; 1 - wrench frame; 2 - pin; 3 - cam; 4 - cam axis; the arrows show the direction of pin's turning and of wrench frame and cam during removal of the pins.

The detachable socket 3 with opening to conform with size of pin 5 is placed in frame 2 and blocked with bolt 4. The pin is then turned into the socket and pressed by bolt 1. The top of frame 2 has edges as a conventional adjustable wrench.

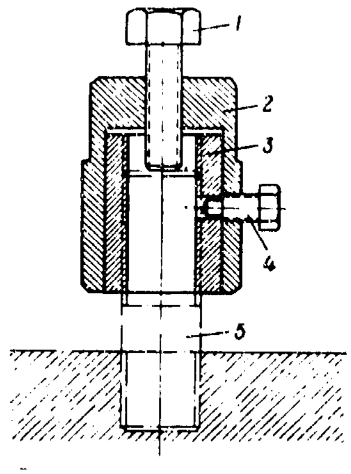


Fig. 51. Socket Wrench with Removable Socket: 1 - check-bolt; 2 - frame; 3 - removable socket; 4 - set (binder) bolt; and 5 - pin.

## Section 20. Replacement of Protective Strips

During prolonged stay in sea water, the zinc platings become completely unfit for use because of corrosion and have to be replaced periodically. The wornout protector is removed with a screwdriver or small bar, the retaining screws (usually with a recessed head) are turned out with a screwdriver or flat pliers. The diver carefully scrapes clean the protector's points of contact and installs a new protective plating.

## Section 21. Installation of New Bottom Fittings

New bottom mountings are installed while the ship is afloat: the kingston valves, depth finders, mechanical logs, and so forth. This is usually necessary in replacing the engines and fittings /77 including the installation of new devices connected with the side.

Figure 52 illustrates the installation of a kingston valve in calm water in the technological sequence.

From within the ship hull, with a perforating gun, a hole is shot in the outer sheathing precisely in the center of the kingston valve's point of installation (Fig.52a), and a wooden plug is pounded in (Fig.52b). Using the plug as a guide, the box-caisson is set up (Fig. 52c). The closeness of the caisson's fitting is checked by brief openings of the plugged hole.

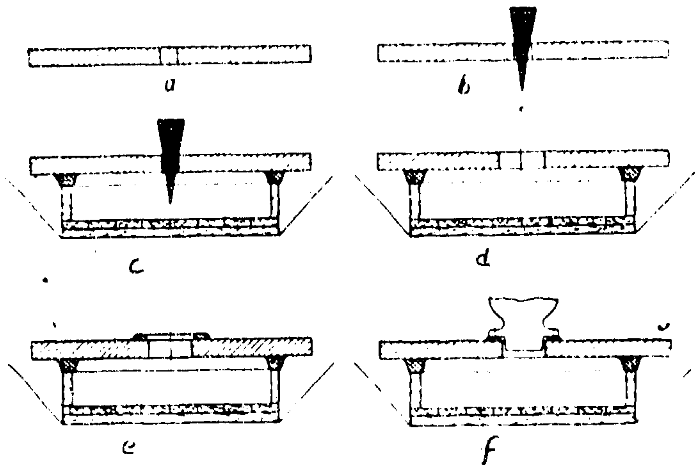


Fig. 52. Diagram Showing Steps Involved in Installing a New Kingston Valve in Calm Water: a - hole shot in the sheathing; b - closer (plug) installed; c - box-caisson in place; d - hole has been cut; e - support ring has been welded on; and f) kingston valve's fittings have been mounted.

Then a hole is cut to conform with the size of the kingston valve (Fig. 52d) and the support ring (Fig.52e) is welded on. For a higher quality welding and to avoid deformation, we recommend that a slight filtration be left and that the support ring be welded under water. In this case, the pins present in the support ring will coincide exactly with the holes in the kingston valve's flange.

The next step is to pump part of the water out of the box-caisson and to fasten the kingston valve's fittings (Fig. 52f). Upon the completion of all the tasks and the closing of the kingston /78
valve, the box-caisson is removed.

Installation of a kingston valve in a current is done without the use of a box-caisson. The succession of steps is shown in Fig.53. In the shaft in the ship's sheathing, a hole is punched (Fig.53a), which is also sealed with a plug (Fig.53b). The diver then utilizes a sealing device, consisting of a rod, cap with a rubber lining, cross members and nuts. On the rod are mounted a mantle (support) ring, flange and frame of the kingston valve (Fig.53c). The required seal is then developed by tightening the nut. After the stoppage of the filtration, a hole is cut from inside the ship (Fig.53d), and a support ring (Fig.53e) is welded on. This work is performed in an above-water position or with the flooding of water, having entered the shaft during the installation of the sealing arrangement (device).

After the fastening of the kingston valve, a flange is mounted on the support ring from above. The sealing device is removed; moreover, at the moment of removing the rod from the kingston valve, a wooden plug is driven into the flange opening. It is necessary to see to it that the rod does not get moved entirely out of the kingston valve prior to the insertion of the plug (Fig.53f). The next step is to close the kingston valve with a sluice valve and to remove the plug.

In placing of the mounting of the sealing device with the rod and cross piece, a metal cap can be placed on the pins. In this case, in the center in place of punching a hole with a gun, we drive in a pin, which serves as a reference point for the installation of the cap. Then, using the holes in the cap as conductors, with the perforating gun we drive the remaining pins around its circumference. The next step is to remove the cap temporarily from the pins, install the rubber lining, place the cap on it, and tighten the nuts.

Further, the seating of the kingston valve is accompl ...ed in accordance with the above-described technique. Upon completing the assembly of the kingston valve, the cap is pulled, the pins are cut off and welded over if required.

The installation of the echo sounders and the logs is similar to that of the kingston valves.

In the repair and installation of the new bottom fittings, just as in the conduct of the other tasks associated with the opening of the side holes, water pumping equipment is made ready and guards are put on duty.

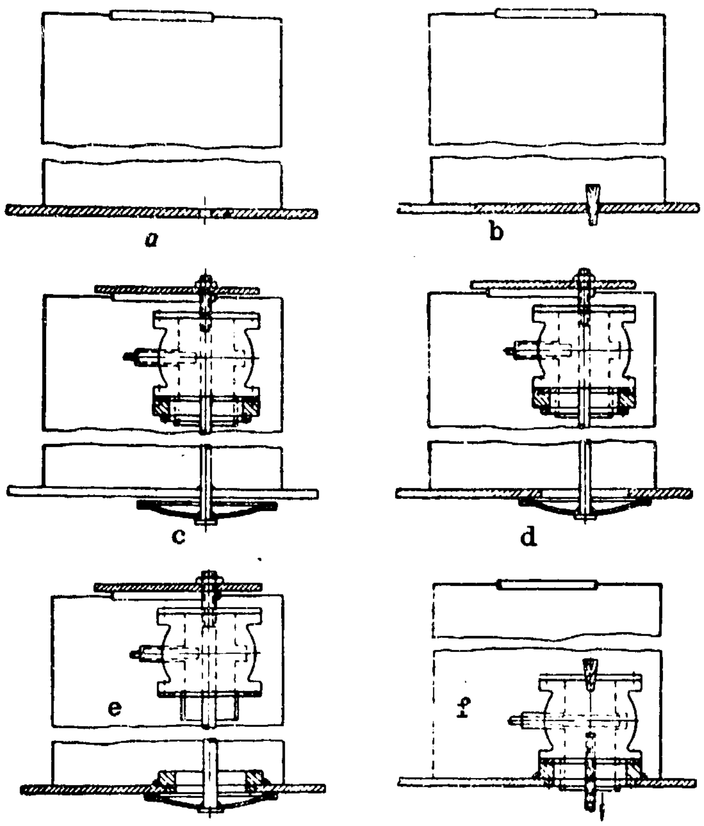


Fig. 53. Steps Involved in Installing a New Kingston Valve in a Current:
a - a hole shot in the sheathing; b - closer (plug) has been fitted; c - moment of applying the device, bolt is passed through the kingston valve fitting, the sluice valve is open; d - device has been mounted and hole has been cut in sheathing; e - mantle (support) ring has been welded on; f - kingston valve installed, moment of removing the device, sluice valve is open; to avoid entrance of water into the shaft, a plug has been inserted in the kingston valve.

# CHAPTER 5

## UNDERWATER WELDING OF METALS /80

Welding is the process of obtaining inseparable joints of solids, characterized by interatomic bonding, and as a result by continuity of the internal structure. In the underwater conditions, use is made only of the electric-arc welding with a melting electrode based on N. G. Slavyanov's technique.

The concept of underwater welding belongs to the famous Russian inventor N. N. Benardos. However, electric arc under water was initially utilized for cutting purposes by Benardos himself, in conjunction with the Russian physicist D.A. Lachinov in 1887.

The first experiments involving the underwater welding with a metal electrode were accomplished in the welding laboratory of the MEMIIT by Academician K.K. Khrenov in 1932. As a result of the research studies, the basic features of the underwater welding process were studied, the first electrodes were developed, and a procedure for performing the tasks was established.

In the literature, examples are described of utilizing underwater welding and cutting during the raising of the "Boris" steamer from a depth of 48 m, in the salvaging of the "Sibiryakov" ice breaker from a rock, in saving the "Ussuri" steamer, during the welding of the water-conducting sag pipes in Leningrad, and also in other instances.

Underwater electric welding and cutting has become quite popular in the emergency rescue, ship-repair, ship-raising and underwater-engineering operations during World War 2.

### Section 22. Features of a Welding Arc Under Water. Lighting and Maintaining the Arc. /81

The heat source during the underwater welding is an electric arc discharge, usually called an electric arc. The arc burns between the continuously melting electrode and the product which is being welded.

Under water, an arc has features which differ appreciably from an arc burning in the air; these features affect the characteristics of the welding process.

Whereas in air, the temperature of a welding arc burning between two iron electrodes will fluctuate within the limits of 5000-6000°K, under water the temperature of the welding arc within the limits of depths not exceeding 10 m, comprises roughly 7000-9000°K.

Under water, the arc is enclosed in a closed vapor gas bubble, maintained by the evaporation and dissociation of water, the combustion products from the product's metal, of the electrode and its mineral coating.

During the burning of the arc in the vapor-gas bubble, a counterpressure is created. The arc so to speak itself creates the conditions for its own existence. According to the research data, the vapor-gas bubble consists of hydrogen, carbon dioxide, carbon monoxide and a small quantity of hydrocarbons and oxygen. As the investigations have indicated, with an increase in the pressure, the hydrogen content of the bubble rises and at a depth of 100 m during welding with coated electrodes, it attains 77.5%.

The increased pressure of the gases in the vapor-gas bubble and also the presence of a slight amount of hydrogen possessing high heat conductance, exerts a cooling effect on the arc. The bubble's walls are mobile, since periodically a part of the gases leaves the bubble, breaking through to the surface.

The perturbation of the welding arc under water is realized just as at the surface by contact of the electrode with the object being welded.

At the instant of the electrode's contact with the object, owing to the contact resistance at the end of the electrode, heat is released which initially causes a heating of the water, follow by steam formation at the place of contact. In this way, a vapor-gas bubble is formed which expands at the moment of separation of the electrode's tip from the object and at the time of the arc's formation. /82

The diagram of the arc's burning under water is shown in Fig.54. Under the effect of the arc's heat, the object's metal melts, forming a welding bath. Its size depends on the electrode's diameter and the force of the welding current. In the center of the bath, a pocket is formed, called the crater. Between the crater's bottom and the electrode, the arc's column is located. The depth at which the object's metal melts under the effect of the arc's heat is said to be the penetration depth.

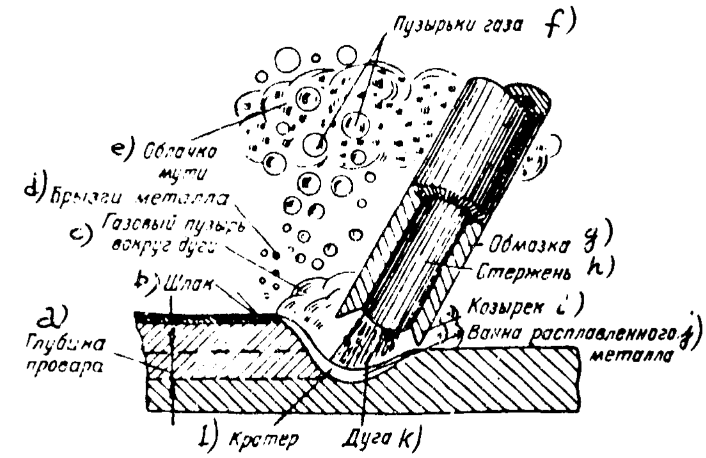


Fig. 54. Diagram Showing Burning of Welding Arc Under Water. Key: a) penetration depth; b) slag; c) gas bubble around arc; d) metal fragments; e) turbid cloud; f) gas bubbles; g) lubricant; h) rod; i) deflector; j) molten metal bath; k) arc; and l) crater.

The quality of the weld is judged from the penetration depth. It is conventional to consider that the greater the penetration depth, the higher the quality of the weld. We therefore recommend that the welding be done with a short arc in order to obtain a greater penetration depth. An arc with a length equalling the electrode's diameter is said to be short. The arc's length usually does not exceed 3-5 mm.

During the welding process, the melting metal of the electrode mixes with the molten metal of the object and forms the welding seam, above which the slag accumulates. During the burning of the electrode's rod, the coating melts forming a deflector, while the combustion products form a small turbid cloud and gas bubbles. The arc's burning is accompanied by a spraying of molten metal, usually associated with the passage of the drops into the welding bath. /83

Depending on the composition of the electrode's coating during manual welding and the composition of the electrode bar, the transfer of metal from the electrode to the seam acquires various forms. The optimum form assuring high mechanical properties is the fine-drop transfer, which typifies the manual underwater welding. The diagram of metal transfer during electric-arc welding is represented in Fig. 55.

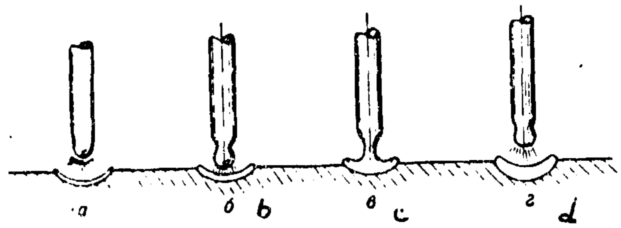


Fig. 55. Diagram Showing Metal Transfer in Arc: a-burning of arc; b-formation of drop; c-transfer of drop into bath; and d-original position.

At the first moment of the arc's burning, there occurs the melting of the electrode end and of the object's metal (Fig.55, a). Then under the effect of the arc's heat, a drop forms on the electrode's tip (Fig.55, b). Under the influence of gravitational force, owing to a weakening of the forces of surface attraction and also under the effect of electrodynamic forces directed along the axis of the arc's column, the drop breaks away from the electrode and transfers to the object (Fig.55c). The arc is then reactivated and the cycle is repeated (Fig.55d).

Welding under water is accomplished with direct current with direct (minus to electrode) or reverse polarity (minus to object) depending on the type of electrodes and the kind of work which is being done. It is also possible to weld under water with alternating current but its utilization is not desirable since with direct current, the conduct of the process of welding and cutting is easier and the arc's burning is more stable.

The welding arc is a conductor of electric current; just as any electric conductor, it is surrounded by a magnetic field. The arc's magnetic field during the welding of large objects, e.g. of ships, boilers etc. interacts with the mass of the object and causes its deviation from the electrode's axis. The arc begins to burn unsteadily (to wander), and welding becomes impossible. This phenomenon has been given the name of the magnetic "blowing" of the arc. /84

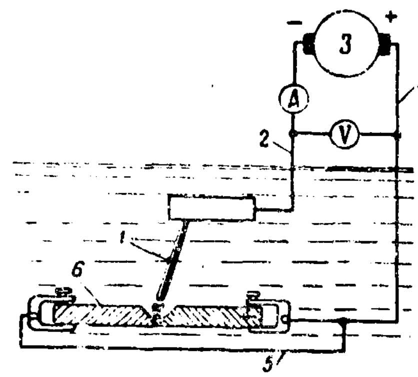


Fig. 56. Diagram Showing Connection of Reverse Line to Object from Both Sides. 1 - electrode; 2 - direct line; 3 - generator; 4 - reverse line; 5 - branching of reverse line; 6 - metal which is being welded.

The wandering (straying) of the arc depends on the concentricity and thickness of the electrodes' coting, on current distribution and other factors. Magnetic blowing is manifested more strongly during welding with DC.

One of the methods of counteracting the magnetic blowing is a change in the angle of the electrode or a modification in the direction of the welding, e.g. from the edge to the center of a sheet. Good results are obtained by transferring the connecting point of the reverse cable to the object closer to the point of welding. Excellent results are also obtained by the branching of the reverse line and its connection to the object from two sides (Fig. 56).

The magnetic blowing is lowered significantly by a careful fitting of the sheets which are being welded and a reduction in the clearances. The arrangement of a work post while welding under water is shown in Fig. 57.

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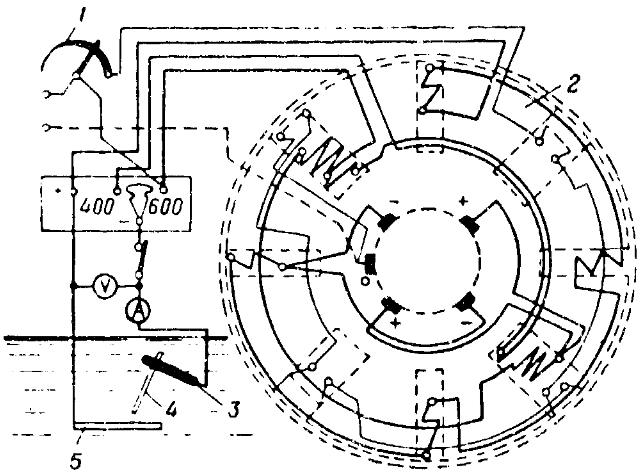


Fig. 57. Layout of Work Station for Underwater Welding: 1 - rheostat; 2 - type SGP-3-VI welding generator; 3 - electrode holder; 4 - electrode; and 5 - product.

### Section 23. Electrodes for Underwater Welding

The electrode used for manual welding under water is a round metal rod 350-450 mm long with a diameter of 4-6 mm.

To the electrode, we apply a concentric uniform layer of mineral coating (smearing). Depending on the brand and diameter of the electrode, the thickness of the coating will vary within the limits of 0.5-1.3 mm on a side. On one end of the electrode, there will remain an uncoated section which serves for conducting the welding current and the attachment of the electrode in the electrode holder.

In the preparation of the electrodes for manual underwater welding, use is made of the steel wire, brand Sv-08A according to GOST (State Standards) 2246-60 (see Appendix 7).

The electrode coating assures a stable process of the arc's burning and improves the quality both of the weld metal and of the welded joint as a whole; it also enhances its mechanical properties, i.e. strength, plasticity and density. This is achieved by including in the smear (coating) the components which complete the burning elements, improve the ionization of the arc gap and the formation of the gas and slag protection of the joint, that is, they form /86 light substances floating to the surface of the weld metal; upon hardening, these substances also cover the hot metal with a slag skin.

The slag skin assures the gradual cooling of the seam (joint) metal and protects it from the penetration of various gases surrounding the arc beneath the water, chiefly hydrogen.

The coating of the electrodes for the underwater welding should have increased strength and should not chip away from the impact of the electrode against the object being welded, during the excitation of the arc, should be elastic so that it will bend together with the rod. During drying and in case of prolonged storage, the coating should not have become cracked, since in the underwater conditions in case of the penetration of water (especially saline), it quickly disintegrates. The composition of the coating of the electrodes is given in Appendix 8.

In addition, the coating should create a strong hydro-and electrical-insulation of the electrode rod, should not swell in water, and during the welding, it should form the so-called "shield" which favors the stabilization of the welding process.

The electrodes designed for underwater welding are unsuitable for working in air. Contrariwise, the electrodes which are utilized for welding in air, with a minor exception, are not suited for working underwater, even if a waterproofing has been applied to them.

In the absence of special electrodes for underwater welding, use is often made of the popular electrodes with the mine-acid coating, brand OMM-5 and TSM-7 (class E42, GOST 9467-60) with the application of waterproofing to them. However, this is not recommended, since as a result of the presense (in the coating of such electrodes) of gas-forming substances, the welded joint turns out to be porous.

Grades (brands) are assigned to the electrodes in accordance with the coating's composition. The most common are the brand EPS-5 electrodes and in recent years, the EPS-52. The technical specifications for the underwater welding electrodes are listed in Appendix 9.

The technique involved in manufacturing the electrodes for welding in air has been exhaustively described in the literature and there is no need to include it here. In addition to the composition of the coating, the electrodes intended for underwater /87 welding differ from the conventional electrodes by virtue of the presence of a waterproofing layer which is applied after the mineral coating, drying and tempering of the electrodes.

Since in the operation of the USRS (Underwater Ship Repair Station) conditions often do not exist for observing the regime for the storage of the electrodes and they become damp, it is necessary to dry them and to restore the waterproof coating directly at the USRS.

The simplest waterproofing is paraffin which is applied to the electrodes in a molten state (the electrodes are placed in the melted paraffin and they are "boiled" for several minutes).

As waterproofing material, use can also be made of Zapon, bakelite lacquer, celluloid thinned in acetone, etc.

Currently, for the waterproofing of electrodes for underwater welding, extensive use is made of perchlorvinyl resin or copolymer of chlorvinyl with venylacetate diluted in dichlorenthane (7% solution).

The waterproofing is accomplished by a three- or four-fold submergence of the coated electrodes in the solution followed by air drying until complete dryness at room temperature after each immersion.

In order to distinguish the grades of the electrodes from one another quickly, on the uncoated ends an identifying paint is applied, e.g. the brand EP-35 electrode (formerly the 27-09) is painted white, while the EPS-52 is left unpainted. The electrodes for underwater welding have not been standardized (GOST specifications have not been written), and the color of the distinguishing shade for them is not regulated. It is necessary to store the electrodes in a dry, cool location. They are packed in sets each weighing from 3-5 kg, are wrapped in parchment or casing paper, and are immersed in melted paraffin.

To each box of electrodes, a label is affixed showing the name of the plant-supplier, the brand of electrode and the coating, the welding conditions and current polarity, dates of manufacture and the stamp of the Technical Inspection Department (TID).

The bundles with the electrodes are packed in wooden boxes, and sometimes in iron cases lined with tarpaper and wrapped with wire. At the present time, it is customary to place 27 kg in each box.

Into each box, the manufacturer inserts a packing list and /88
certificate of the electrodes, or instruction for their use. During transportation, the boxes containing the electrodes should never be thrown.

## Section 24. Tools and Fittings for Underwater Welding

The electrode holder for underwater welding is the principal tool used by the diver-welder. Among the various designs of the electrode holders for underwater welding, for simplicity and reliability of operation, we can recommend the EPS-2 electrode holder, having become most popular in the fleet (Fig. 58).

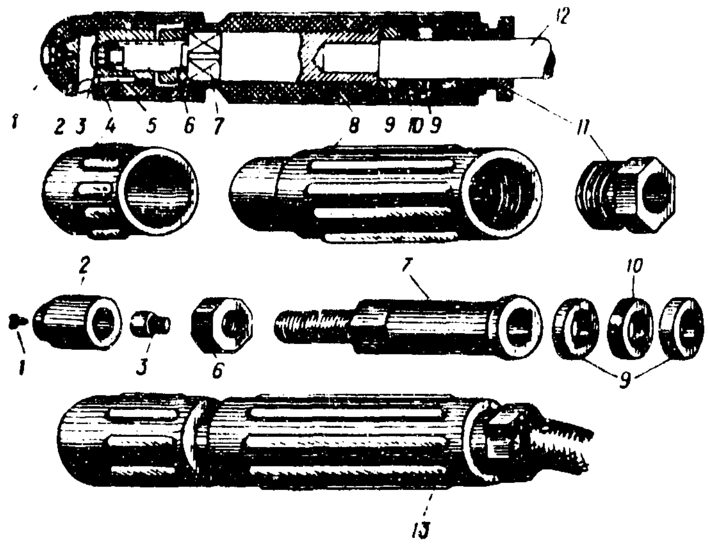


Fig. 58. Electrode Holder for Underwater Welding (Holder Is Type EPS-2): 1 - stay screw; 2 - sleeve; 3 - contact nipple; 4 - textolite cap; 5 - key; 6 - pressure nut; 7 - rod with filed square section; 8 - handle; 9 - brass rings; 10 - rubber sealing ring; 11 - stuffing box-type bushing; 12 - welding cable; and 13 - outer view of electrode holder.

Onto the brass or bronze current-conducting rod 7, with a recess for the sealing in of the welding cable 12 on one end, and a thread on the other, there is screwed on the brass (bronze) sleeve, 2. In sleeve 2, a hole is provided for accomodating the /89 electrode. Rod 7 is inserted into the textolite handle 8, forming the frame of the electrode holder, while sleeve 2 is inserted into the textolite cap 4, forming its head. Rod 7 is shorter than handle 8, therefore the sealing (soldering) of welding cable 12 proves to be within the frame.

The frame's airtightness on the side of the cable is provided by one rubber ring, 10, and by two brass rings, 9, compressed by the gasket bushing 11. Rod 7 is held in handle 8 with the aid of the pressure nut 6, and to avoid turning in handle 8, on rod 7 a square section is filed, which is placed in the corresponding square hole within handle 8. Sleeve 2 is fastened in cap 4 by screw 1 and key 5.

The electrode is inserted by its uncoated end into the holder's head. Pressure is exerted on the electrode by turning the head clockwise as far as it will go, i.e. until the contact nipple 3 of rod 7 rests against the electrode's lateral surface.

Replacement of the electrodes is accomplished in reverse order: the head is turned counterclockwise and the released electrode stub (or the electrode) falls out of the hole. The holder is so arranged that the compression and extraction of the electrode are each accomplished by turning the head within the limit of one turn. If the electrode stub fails to drop out when the head is released, the holder should be shaken or (after having made certain that the welding circuit is cut off), one should pull out the stub by hand. However if the electrode stub still does not come out, one should tap it lightly with a hammer or wiggle it back and forth.

The EPS-2 electrode holder is intended for use with the electrodes ranging in size from 4-6 mm diameter and for a maximal current force of 400 amps. We solder into the holder a piece of brand NRSHM or RSHM cable with a section of 50 $mm^2$, a length of 1.5 m fitted with a cable adapter or with a connecting half-sleeve.

In working with the holder, one should pay attention to its airtightness (sealing of the frame, head and connections), and in the process of operation, one should periodically clean the contact nipple 3.

The auxiliary tools used by the diver-welder consist of a hammer, a cutter or chisel, end type and flat wire brushes for cleaning the points of welding and the joints (Fig.59). In addition, /90
we recommend that one have a feeler gage for checking the clearances and the correctness of fitting of the sheets or of the patches on the sheathing (Fig.60). For cleaning the joints, one can also utilize a pneumatic or electrical tool.

The tool is lowered to the welder on a rope (pendant) or in a bucket with a screen bottom.

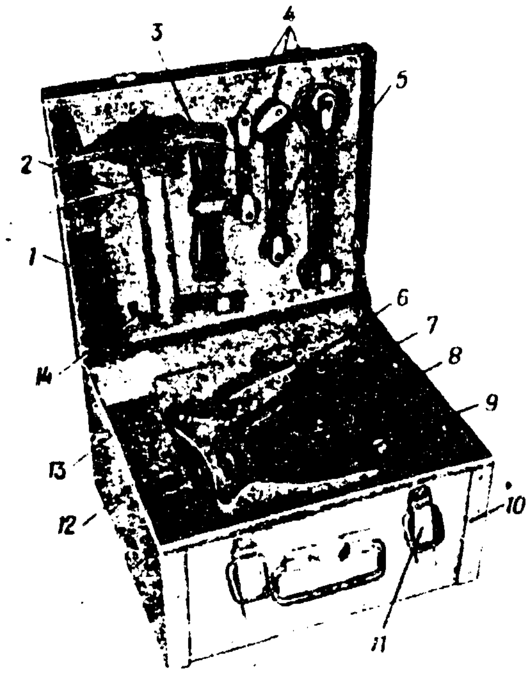


Fig. 59. Tool Kit for Underwater Welding and Cutting: 1 - flat wire brush; 2 - hammer-cutter; 3 - end type wire brush; 4 - open-end wrenches; 5 - lid; 6 - fitting for oxygen tank; 7 - clamp; 8 - EPS-2 electrode holder; 9 - reducer; 10 - box housing; 11 - lock; 12 - compartment for expendable material (cloths, lashing wire); 13 - official location for documentation; and 14 - special key.

For protecting the diver-welder's eyes, use is made of the /91
type ES dark glass (light filter), just as during the welding at the surface, only it is a lighter glass mounted in a special adjustable type of device which is fastened to the rim of the front illuminator in the diving helmet and can be tilted according to the desire of the diver (Fig. 61).

It is recommended that the tools for underwater welding and cutting be organized in a standard packing box. Such a kit (Fig. 59) for the tools and a small quantity of expendable materials (for the first case of an accident) should always be kept in proper order and ready for immediate use.

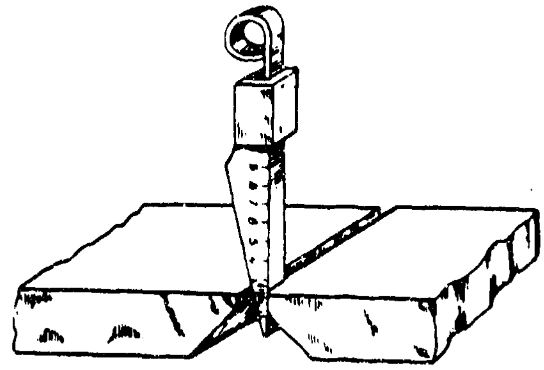

Fig. 60. Feeler Gage for Measuring the Clearances.

The kit should include: electrode holders for underwater welding and cutting; a dual-chambered oxygen reducer; a protective device (light filter) for insertion in the front light of the diving helmet to the triple-bolt diving suit; connecting half-sleeves, a clamp for connecting the result cable to the object being welded, with a cable piece having a section of 50 mm$^2$, brand RSHM with a length of 250 mm; a cutting hammer, wire brushes (flat and end type), open-end wrenches, a screwdriver; an attachment to the oxygen tank and expendable material--brass wire for the lashings, insulation tape, silk-reinforced rubber and cleaning cloths.

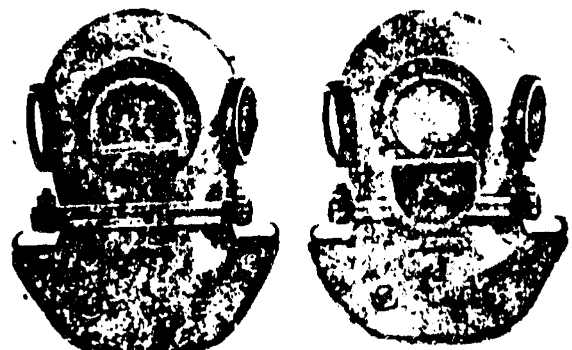


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Fig. 61. Device with Protective Glass in Front Light of Diving Helmet: a - position of protective glass during welding; b - position of protective glass during work breaks.

In addition to the storage box, the kit should also include two reels to the cable, brand RSHM with a section of 50 mm$^2$, and each 75 m in length; an oxygen feeder hose with diameter of 9.5X18 mm with a length of 60 m (three hoses each 20 m long) equipped with adapters; six packets of electrodes for underwater welding and an electric-oxygen cutter; instructions for the operation of the equipment, its technical certification and instructions for the welding and cutting of metals.

For convenience in the diver-welder's work, the cable used for underwater welding should be fairly flexible. Its cross section in the sector directly fed to the diver-welder should not exceed $70mm^2$. The cable should have reinforced insulation, be resistant to sea water and to petroleum products (solar oil, mazut/residual oil/, etc.).

For the underwater welding, use is made of the brand RSHM or NRSHM cable. The welding circuit should have direct and return leads. One should never utilize the hull of the ship being repaired or of the salvage ship as a return lead, since the electrolysis causes an intensified corrosion of the ship's hull.

The flexible welding cable is stored on the ship on reels of 50 m each and is rigged at the ends with cable adapters or with connecting half-sleeves. /93

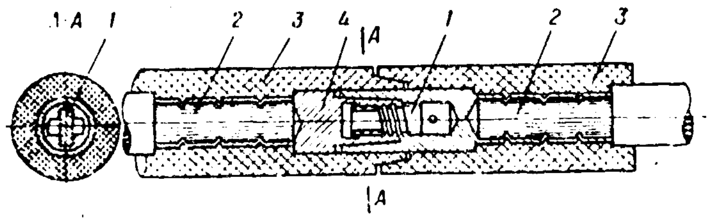


Fig. 62. Connecting Sleeve for Welding Cable During Underwater Welding: 1 - plug; 2 - welding cable; 3 - rubber insulation; 4 - socket nut.

The connection of the standard cable adapters is realized with the aid of a bolt and nut. To avert wetting the contact and the leakage of current, the connecting point is carefully covered with insulating strip. However, as experience indicates, such a joint does not guarantee airtightness and soon becomes disrupted during work in sea water.

The cable connecting sleeves are more reliable. Several designs of the connecting sleeves are available: with bolt or without bolt;

with soldering of leads, or without soldering; with the utilization of an expansion-type cone, and so forth.

The sleeve's design (Fig. 62) assures rapidity of action and complete sealing. For connecting the cable, it suffices to insert one half-sleeve into the other and to turn them by ¼ turn relative to one another. The second (return) lead is connected to the object (being welded) with a clamp.

### Section 25. Power Sources for Underwater Welding

The DC welding generators serve for powering the welding arc. A feature of these generators is the drooping volt-ampere characteristic. By volt-ampere characteristic, we connote the curve of dependence of voltage variation at the external generator terminals on the load current.

According to the conditions of the process, the voltage at the welding generators' terminals should decrease with an increase in the welding current, while in case of a short-circuit, when voltage at the terminals equals zero, the short-circuiting current should not exceed the working current by more than 1½ - 2 times. The current sources supplying the welding arc under the water should have intensified power and no-load voltage to assure easy ignition and stable burning of the arc, without ceasing to function if there is a short circuit, and quickly restoring the voltage following a short-circuit condition.

According to GOST 304-51, 10594-63, the welding generators should restore the voltage after a short circuit up to 25 volts within 0.05 second. The no-load voltage should not be below 65-70 volts, while for deep-water operations, it should not be under 85-90 v. The welding generator should provide a rated force of welding current amounting to 350-400 amps and its regulation within wide limits.

For underwater welding under autonomous conditions, use is made of the DC welding installations equipped with a primary motor.

They are normally set up on the upper deck of the ship under repair or on an auxiliary floating drydock. In connection with this, the autonomous welding installations should moreover provide normal operation at ambient air temperature in the limits of +40°C to -25°C; relative humidity to 95%; vibrations up to 2,000 fluctuations per minute, with amplitude ranging from 4 to 0.3 mm and inclination angle of ±15°.

The welding installation should have a cover to protect it from precipitation and should be completely covered with metal blinds; it should have an eye bolt for hoisting with a crane and rollers underneath so that it can be moved about the ship deck. The design of the welding installation should permit repair without removal from its frame. The insulation must be moisture-resistant while the generator should be a spray-resistant model provided with self-ventilation. The following types of welding machines can be employed for underwater welding.

1. Stationary type of welding installations--machines for commercial use, type SMP-3-IV or in the marine model--SAM-400, SAM-400-1, and others.

The technical specifications of the welding installations are presented in Appendix 10. /95

Each of these installations consists of a welding generator and of an electric motor installed on a common mounting base and connected by a flexible sleeve. Such installations are placed in the enginerooms or in specially designated areas.

2. Mobile welding installations: these are the welding transformers PS-500, PSO-500, PSU-500, wheel-mounted in the single-frame design equiped with the flange type of electric motor, mounted on one shaft with the generator armature; the technical specifications are listed in Appendix 11;

--the autonomous welding installations with internal combustion engines mounted on a rigid metal frame, type SPAZ-3a, PAS-400-VI, PAS-400-VIII, ASD-3-1, ASDP-500 and others; the carburetor-type of engine is connected with the generature armature by a sleeve joint; the installations are provided with the type SMG, GS and SGP welding generators.

Control of the welding current's force is adjusted in these generators with a rheostat connected in-series in the circuit of the excitation shunt-winding. The motors in the installation are furnished with starting-control equipment, measuring devices and an automatic voltage-reduction unit (ASN-55). This unit is intended to assure safety in the underwater welding activities and fuel economy during work interruptions.

At closing of the welding circuit, the ASN-55 acts on the engine carburetor, opening the throttle valve, by the same token raising its rpm to the nominal, and providing the necessary voltage to the terminals of the welding generator. The circuit of the ASN-55 and the point of its installation in the PAS-400-VI welding apparatus are shown in Fig. 63.

The technical specifications of the autonomous welding units are shown in Appendix 12. The diagram indicating the hookup of the type SGP generator for welding is given in Fig. 57.

The AC type STE-32, STE-34, STN-450, STN-500 and STN-700 welding units can also be utilized for underwater welding.

The type STN welding transformers are manufactured in a single-frame model with a built-in current regulator. In them, the primary (connected) voltage is 220/380 v and sometimes 500 v; /95,96
the second voltage is 60 v. The type STN-450 transformers are made in a marine model and have a secondary voltage of 70/90 v. They possess greater power, have an abruptly drooping (falling) characteristic, are designed for manual welding (cutting), and allow a short-term load up to 800 amps.

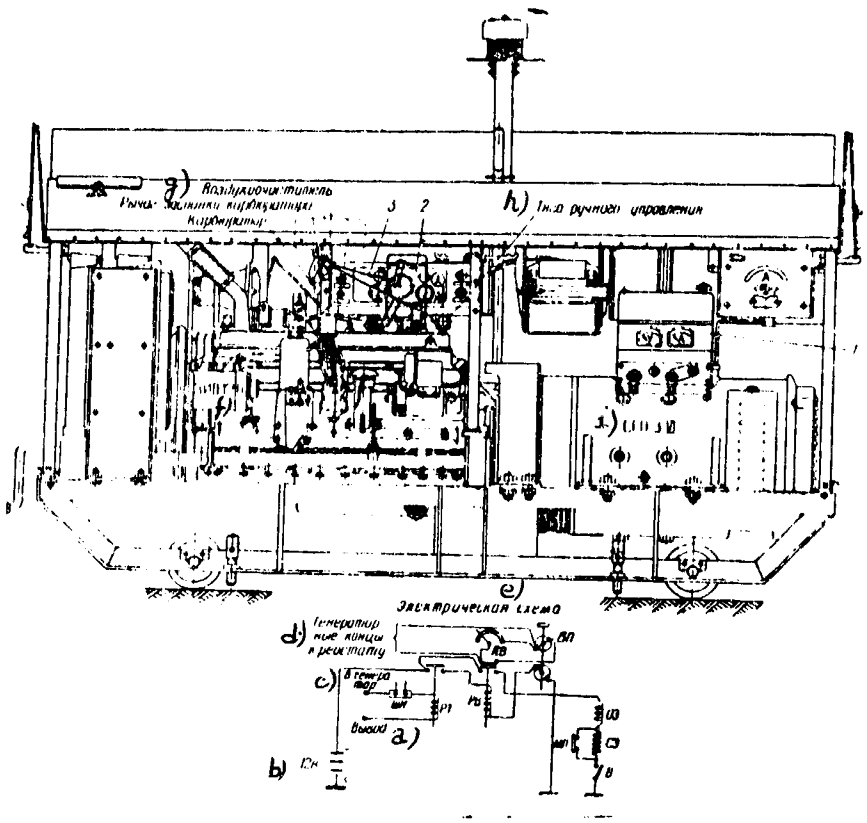


Fig. 63. Electric Circuit of ASN-55 Automatic Unit and the Points of Its Installation on the PAS-400-VI Welding Apparatus: PT = current relay; PB = time relay; RB = rheostat for generator excitation; B = packet-type cut-out switch; O = electromagnetic winding; C = fuel economy resistor; ШИ = measuring shunt; M = microswitch; B = cut-out switch; 1 - point of installing current relay and time relay; 2 - point of installing the electromagnet; 3 - small cable linking the electromagnet with the throttle valve. Key: a) Outlet b) 12 volts; c) to generator; d) Generator terminals to rheostat; e) electric circuit; f)ZIL-120; g) Air cleaner. Lever to carburetor valve; Carburetor; h) manual control rod; and i) SGP-3-VI.

The welding units are produced in mobile models on rollers.

Technical specifications of the welding units are indicated in Appendix 13.

At the present time, alternating current is becoming popular on the ships; therefore the welding rectifiers providing welding with the use of direct current are of great potentiality for underwater welding.

## Section 26. Certain Questions Involved in the Operation Of Welding Machines

The general questions pertaining to the operation and care of the welding machines are discussed in the pertinent instructions and descriptions issued along with the machines. Let us review the individual problems in the operation of the welding generators which are of interest during operation under autonomous (marine) conditions.

An increase in the strength of the power source is conducted when the power from the welding generator (installation) is insufficient; for instance, for the arc cutting of cast-iron or bronze propellers under water, where increased current force is required, or in the event that, for the underwater welding, use is made of the nonspecialized welding systems. For this purpose, we conduct the parallel connection of two standardized units.

The simplest system for connecting two units for parallel operation is the external connection of the outlet terminals of the poles having the same sign, at the generators of these units, i.e. plus is connected to plus, while minus is connected to the minus (Fig. 64).

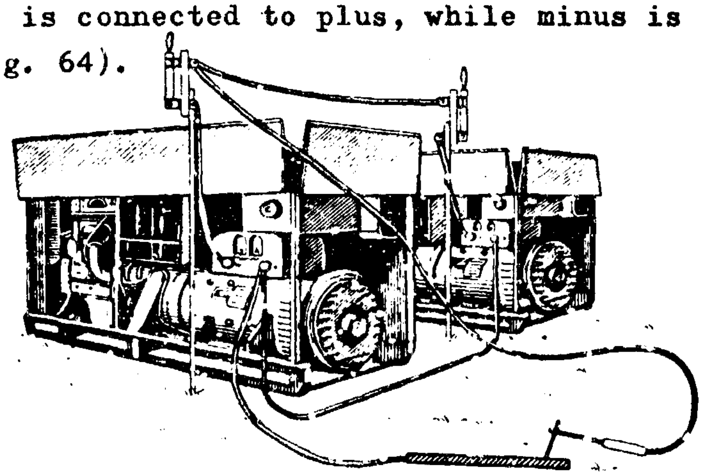

Fig. 64. Simplest Connection of Autonomous Welding Unit for Parallel Operation.

For connecting (for parallel operation) the self-excited welding generators type SMG, SGP, GS, having the extra brush S (C), we conduct the cross connection of the excitation field windings according to the system depicted in Fig.65. In this connection, the extra brushes C are disconnected from the winding of the transverse poles and are connected crosswise by a lead which is 1.5 – 2.0 mm$^2$. In the units hooked up for parallel operation, we compensate the no-load voltage and the load current. /98

In the parallel functioning of two units with internal combustion engines, in addition to the balancing of the generators' no-load voltages, it is necessary to balance the number of engines' rpm and to maintain them during the process of operation.

Utilization of nonspecialized machines for welding, e.g. of the standard power generators with shunt-type and compoun excitation, can be conducted in unusual or emergency cases. On the various kinds of ships, the type PN (having a shunt and light series winding) are most suited for this purpose. In this case, we connect the terminals of the series winding and we obtain the so-called anticompoun network.

The voltage surplus is absorbed by a ballast resistor, connected in-series to the welding circuit. As a ballast resistor, we utilize only metal rheostats under marine conditions; they are strong, convenient to handle, provide constant resistance during operation and permit their being mounted.

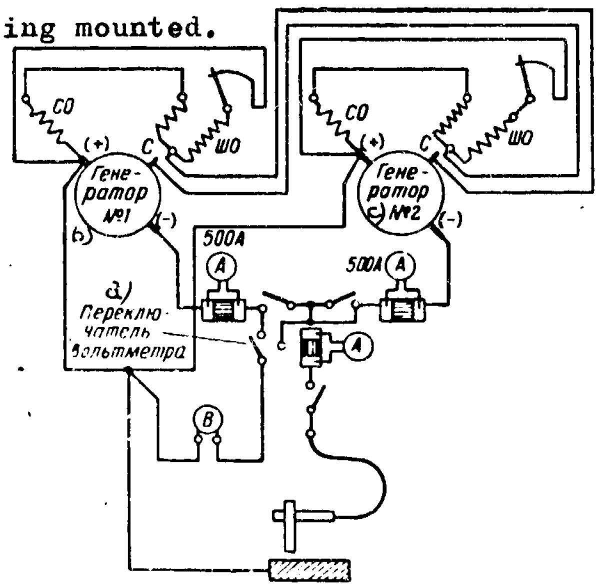


Fig. 65..Main Wiring Diagram for Connecting Two Generators, Type

SMG, SGP, and GS for Operation (equipped with extra brush): CO - series winding; O - shunt winding; and C = extra brush. Key: a) volt-ampere switch; b) generator No. 1; c) generator No. 2.

For the welding from the DC marine generators, use is made of various designs of switching devices: for instance, the type USK-58 (Fig. 66) setup, which can be recommended for employmant on ships in emergency situations.

The USK-59 unit is installed permanently on shipboard. It consists of a switching panel 3; of two control rheostats: one coded with the number 2 - type R-1, and 7 --type RB-300; of an external panel board 6 of the welding circuit, and of a box containing fuses 4. The USK-58 provides switching, to welding and cutting regimes of the marine generators 5 (DC, type PN) or others with compount excitation, with a power not below 30 kw, if the rated generator current can support the welding operations.

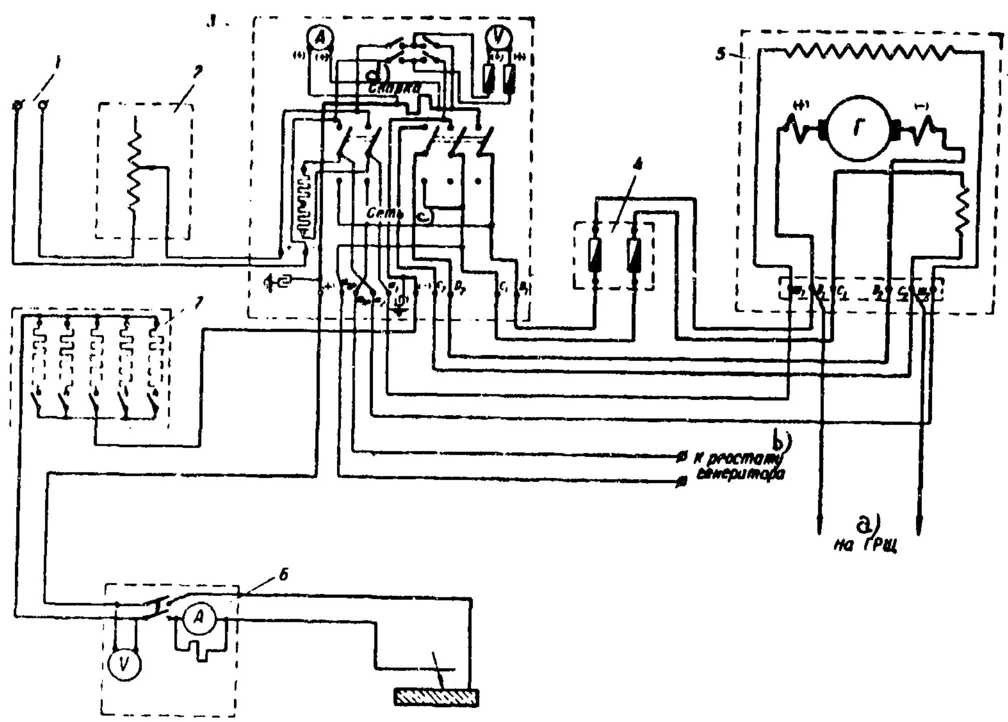


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Fig. 66. Main Wiring Diagram of Switching Unit, Type USK-58 for Welding from Marine Generators: 1 - power supply to independent

excitation; 2 - control rheostat; 3 - switching panel; 4 - fuses; 5 - marine (ship) generator; 6 - external welding panel; 7 - type RB-300 rheostat; 1, 2 = shunt winding; $C_1$, $C_2$ = series winding; $D_1$, $D_2$ = supplemental series winding; V = voltmeter; and A = ammeter. Key: a) To GRSHCH; b) to generator rheostat; c) circuit; d) welding.

In the utilization of this unit, we provide a steeply-falling /101 external characteristic, with a no-load voltage not lower than 80 v, and a short-circuit current not exceeding the working current by more than 50%. The rated current force at PR--100% is 200 amps, while at PR--65%, it is 300 amps. The weight of the USK-58 unit (without the cables) does not exceed 125 kg.

On the panel of switch 3, the knife switches have two positions: "Welding" (toward the top) and "Ship network" (toward the bottom). For welding operations, the knife switches on the panel are shifted from the lower position ("Ship network") to the upper position ("Welding") at nominal engine rpm; in this connection, there occurs a transfer of the series winding terminals from matched to reverse connection, and the conversion of the shunt winding to independent power supply.

When the system is prepared for welding and the welding cables are connected, the diver-welder is lowered; having prepared for the work, he issues a command, after which the knife switch on external panel 6 is activated.

The switching panel is mounted in the generator compartment not far from the ship generator, while the external panel with the voltmeter and the ammeter for monitoring the welding process are installed on the upper deck.

On the ships where the stationary welding system has been installed, the external panel is utilized as a reserve, while with the aid of a bridge, the welding current is fed directly to the welding network.

The switchover of the generator from welding conditions to normal operation is conducted in reverse sequence. The switching of the ship generator to welding can be conducted only at rated engine rpm. In the operation of the USK-58 unit, we observe the requirements stipulated in the rules for operating electrical equipment.

## Section 27. Basic Information on the Technique of Underwater Welding

Preparation of the metal for welding under conditions of underwater ship repair is conducted chiefly on the outer sheathing and framing of the ship.

Since it is quite difficult to perform the welding tasks under conditions of poor visibility and limited state of the diver-welder's movements, the preparation for the welding is performed with particular care. /102

The welding points are cleaned to a metallic luster, removing all dirt, paint, rust and oil. With respect to the point of applying the seam, the parts being welded are carefully fitted together, with retention of the minimal technological clearances. In case of the overlap welding of patches, it is desirable not to have gaps, or in any event, they should not be in excess of 1-1.5mm.

**Classification of Welded Joints and Seams.** By welded joint, we connote the part of a product in the point where its individual elements are welded together.

Welded joints are usually butt type, overlapping (lap), tee joints and in part the joints formed by electric riveting or cutting. Butt-welds are rarely utilized.

In the butt-type of joint, the elements subjected to welding are located in one plane and are fitted by their sides or ends.

The nature of the preparation of the edges of sheets being joined in underwater conditions differs from the preparation of the edges at the surface (Fig. 67).

The preparation of the edges depends on the thickness of the sheets which are being welded: in the butt welding of sheets with a thickness up to 8 mm, the edges may not be bevelled (Fig.67); at a thickness ranging from 8 to 15 mm, a V-shaped finishing is made, while at thicknesses of 14 mm and above, an X-shaped finishing is made. Since the warping during underwater welding is less than in the air, the angle of opening formed by two butt-fitted bevelled edges is made at 89-90°, the amount of blunting is 4-5 mm, and the clearance between the edges is 0.7-1.5 mm. During the underwater conditions, the chamfering of the edges is conducted manually with a chisel or with a pneumatic tool.

In the lap type of joint, the sheets which are being welded are superimposed by their plane surfaces. This connection is the basic one under the conditions of underwater ship repair (Fig.67 b). In preparing the edges, it is necessary to pay attention not only to the cleanliness but also tightness of the sheets' fitting together (tolerable clearance not to exceed 1-1.5 mm). /103, 104

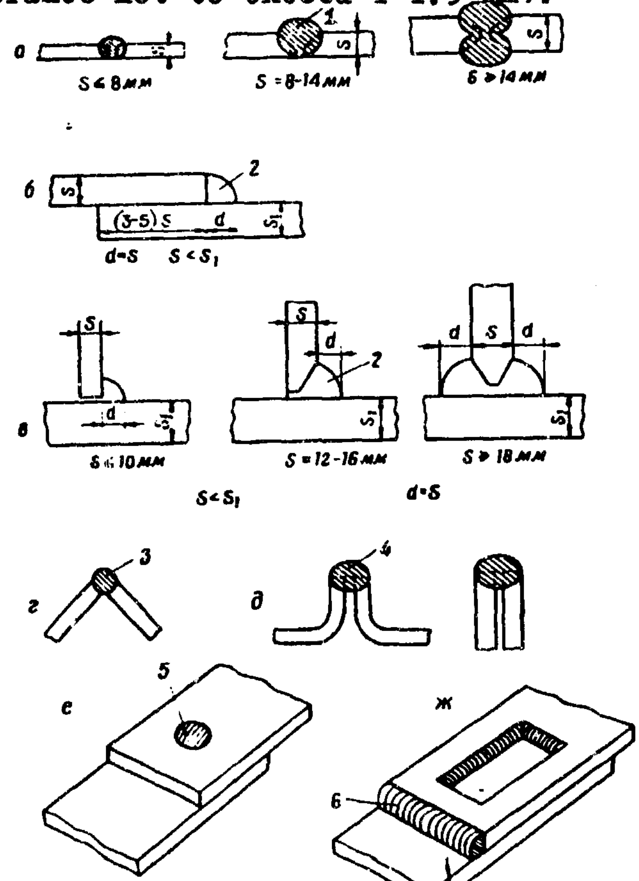


Fig. 67. Types of Welded Joints and Seams: a - butt joint; b -

lap joint; c - tee joint; d - angle joint; e - end joint; f - joint formed with electric riveting; g - cut joint; 1 - butt seam; 2, 6 - bead weld; 3, 4 - fillet weld; 5 - electric riveting; S, $S_1$ - thickness of metal being welded; and d - cathetus of welded joint.

In case of the tee joint or the butt joint, one of the sheets being welded is placed with its lateral surface against the lateral surface of the other sheet; depending on the sheet thickness, we make a single- or double-sided beveling of the edges at an angle of 55° while the clearances are established as in the lap joint.

Angular joining forms a particular case of a tee joint and is accomplished with or without a beveling of edges, depending on the thickness of the sheets which are being welded (Fig. 67d).

Connecting the pieces with electric riveting or cutting comprises a specific case of lap joining. It is utilized when there is no access to the edges of the sheets, for example during the repair of the rudder fin, and also for the reinforcement of a lap joint or for protecting sheets from bulging.

The diameter of the electric rivet is equal to three thicknesses of the sheet which is being welded. We recommend that one countersink the openings at an angle of 45°. Only the upper sheet is drilled.

In the slot, the width of the groove also equals three thicknesses of the sheet which is being welded (with chamfering of the edges at an angle of 45°), while the length is determined by the actual dimensions of the sheets or the design.

In case of the edge or side welding (Fig. 67e), the sheets which are being welded, with a thickness up to 7 mm are superimposed, their edges are lined up and welded, while on the sheets with a thickness of over 7 mm, we chamfer the edges at 45° (opening angle of 90°).

The welded seam is the part of the welded joint which is formed during the welding process.

The design elements of the welded seam are: its height, equalling 0.7 of the cathetus; the cathetus, equalling the thickness of the thinner of the sheets being welded, and its length, which is established by the actual dimensions of the product.

According to arrangement in space, the welded seams (Fig. 68) are divided into downhand (ranging from 0 to 60° to the horizon); vertical (ranging from 60 to 120° to the horizon), horizontal (in a vertical plane), and overhead type (ranging from 120 to 180° to the horizon),

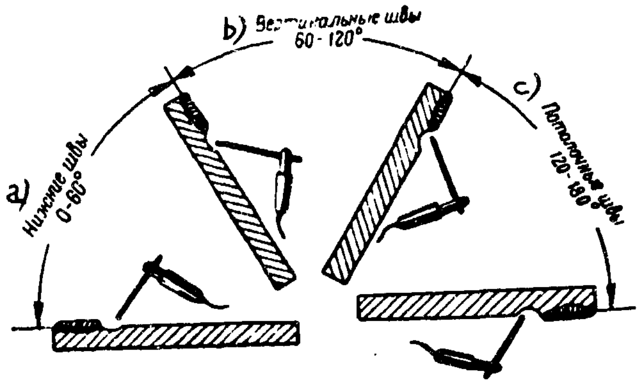


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Fig. 68. Classification of Welded Seams According to their Orientation in Space.
Key: a) Downhand seams; b) Vertical seams; and c) Overhead seams.

We differentiate the semi-overhead, occupying an intermediate position between the vertical and overhead seams (100-130°). The welding in the semi-overhead position is encountered under the conditions of underwater ship repair, in the points of transition from the rounded part of the side to the extremities of the ship, on the bilge outlines etc. (see Fig. 68d).

According to form of section, the welded seams are divided into reinforced (Fig. 70a), normal (Fig. 70b) and weakened (Fig. 70c).

With reference to length, the welded seams are divided into continuous (Fig. 71a), and discontinuous (Fig. 71b); the latter are divided into checkered (Fig. 71c) and chain types (Fig. 71d).

The defects of the welded seams are usually internal and external; they reduce their strength and plasticity sharply.

Among the internal defects, we include the gas bubbles, inclusions of oxides and harmful admixtures, cracks not emerging to the surface, and so forth.

Among the external defects (Fig.72), we include the undercuts a, the nonfusions b, burned spots, saggings, rough craters, externally visible cracks and pores. For the underwater welding, owing to poor visibility and inconvenience of working in diving gear, the following defects are typical: iregularity of the seam in width and height, omissions (discontinuity) and displacement of the seam (Fig. 73). /106

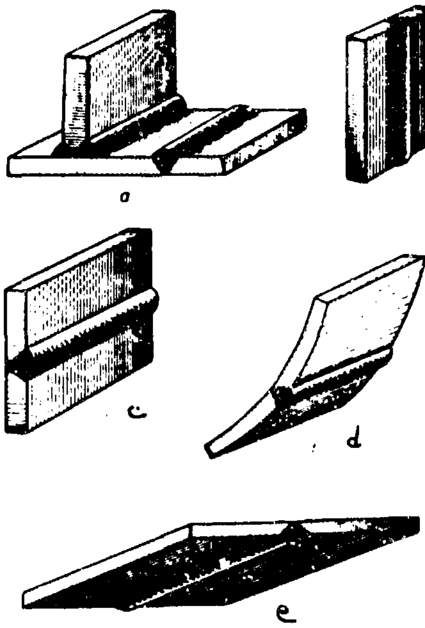


Fig. 69. Arrangement of Welded Seams in Space: a - downhand (flat position); b - vertical; c - horizontal; d - semi-overhead; and e - overhead.

The welding defects, visible to the naked eye and those detected with special instruments, are cut out and rewelded. A slight drift of the seam to one side is corrected by the application of several (2 or 3) parallel beads.

In the welding up of the defective sectors, the beginning of the application of the new seam should be in line with the defective spot, while upon completion of the welding, the crater is diverted to one side so that the useful cross section of the seam would not be weakened.

The technique of applying the welded seam is determined by the nature of the joint, by its orientation in space, and by the preparation of the edges. /107

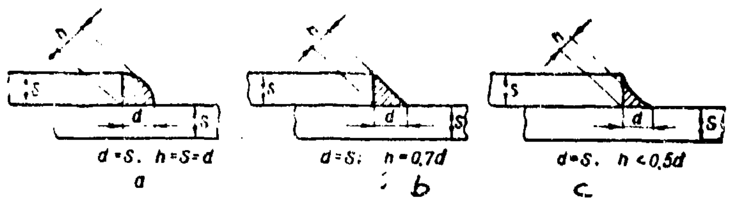


Fig. 70. Classification of Welded Seams by Cross Section: a - reinforced; b - normal; c - weakened; S - thickness of sheets subjected to welding; h - height of seam; and d - cathetus of seam.

In the manual underwater welding, the presence of a coating shield at the electrode permits us to hold a short arc. In this case, the electrode rests lightly on the shield, is handled like a pencil on paper, rocking movements are accomplished with the end, and one gradually lowers one's hand (Figs. 74-77).

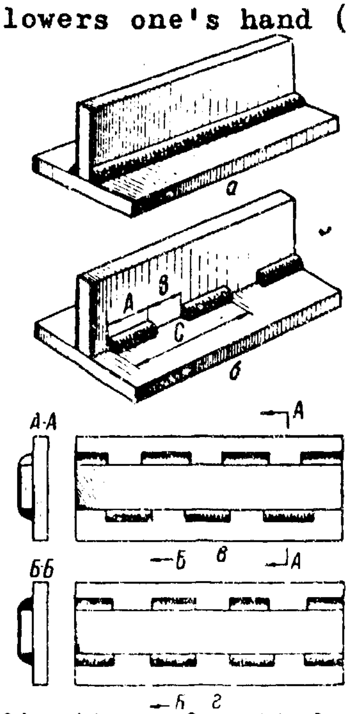

Fig. 71. Classification of Welded Seams by Their Length:

a - continuous; b - discontinuous; c - checkered; d - chain type; A - seam length (40-200 mm); B - distance between seams (60-300mm); and C - spacing of seam (100-500 mm).

The possibility of even a slight but perceptible contact helps the diver-welder to conduct the continuous welding process, which (in the underwater conditions with poor visibility and confined motions, when the work is done almost blindly) has great significance since it affords the possibility of obtaining a welded seam of higher quality.

The diver monitors the welding process through the front light in his helmet.

The manipulations of the electrode and the inclination angle of the electrode during the buildup of the beads and the welding of seams under underwater conditions in a vertical position are /108
portrayed in Fig. 74. The arrows indicate the direction of moving the electrode's tip.

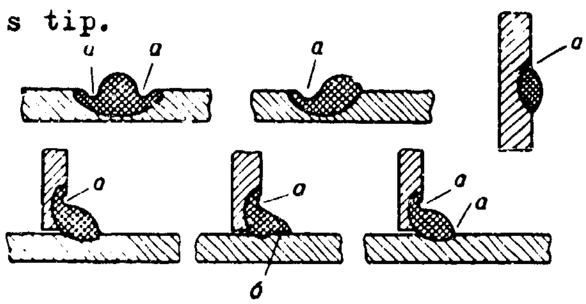


Fig. 72. External Flaws in Welded Seam: a - undercuts; and b - nonfusion.

In case of continuous beading, the bead surfaces are overlapped (Fig. 75).

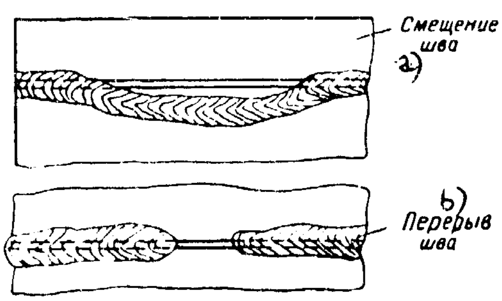


Fig. 73. Drift (Displacement) and Break in Seam During Underwater Welding. Key: a) displacement of seam; and b) break in seam.

Welding of a butt joint with V-shaped finishing is accomplished by transverse and longitudinal motions of the electrode tip (Fig.76).

The rocking motions when welding under water are performed somewhat more rapidly than when welding in air, since the slow motions fail to provide the opportunity of maintaining a bath of the required dimension. The welding of thick sheets is done in several layers (Fig. 77). The first bead is placed in the apex of the angle formed by the beveled edges, without swaying motions--"in the form of a thread" with an electrode of smaller diameter. /109

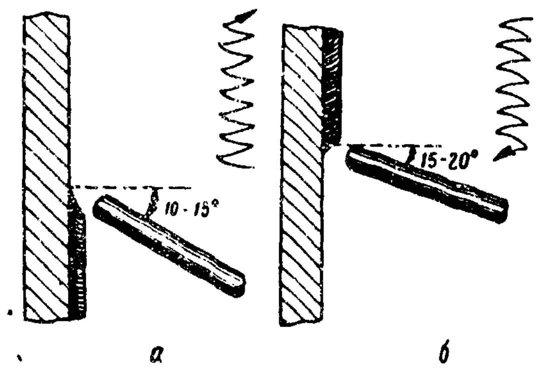


Fig. 74. Swaying Motions with Electrode Tip During Welding and Beading on a Vertical Plane: a - from below upward; b - from above downward; the arrows indicate the direction of the electrode tip's motion.

After cleaning the seam of slag and spatters, the next bead is applied with rocking motions until the entire section of the joint becomes filled. The final decorative layer is applied with a covering of the joint's upper edges.

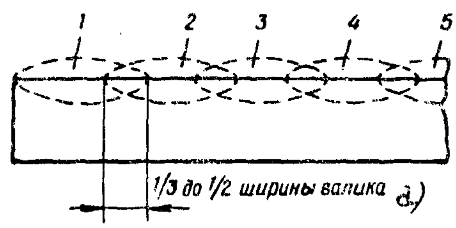


Fig. 75. Application of Beads in Continuous Buildup of the Surface: the broken lines indicate the beads; the numbers refer to the order of applying the beadings. Key: a) 1/3 to 1/2 of the bead's fillet's width.

Sheets with a thickness of 8 - 10 mm can be butt-welded without chamfering the edges, by using a two-sided seam. Prior to the application of the second seam, we carefully remove the slag and we even undercut the seam root with a chisel from the back side. This is recommended in all cases of welding from the /110
reverse side and in individual cases also in the multilayered welding and beading when other methods have not been successful in removing the slag and the leftover spatterings of metal.

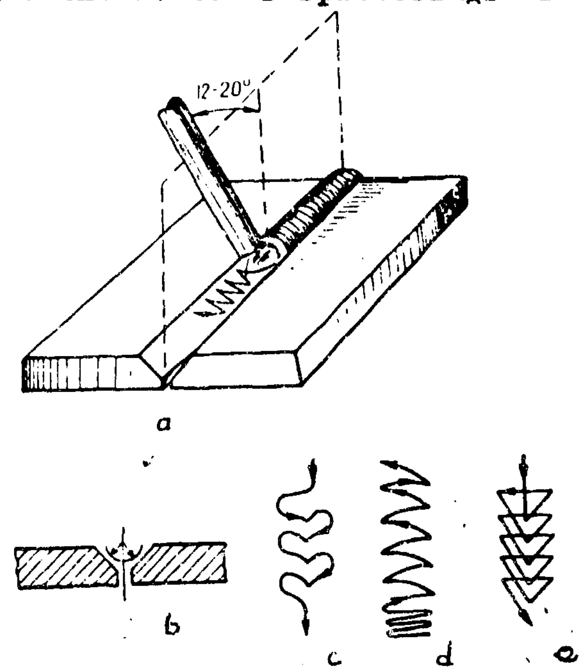


Fig. 76. Movement of the Electrode During the Welding of a Butt Joint with a V-Shaped Finishing: a, b, c -- angles and motion of the electrode in flat position; d - motion of electrode in vertical position; e - motion of the electrode in the overhead position.

In the butt welding without beveling, the edges of the sheets should be trimmed evenly (smoothly).

The inclination angle of the electrode during the welding, with a fill joint, of the lap joints comprises 45-65° and depends on the spatial positions (Fig. 78) in which the welding is performed.

In order to observe better the formation of the seam and the conduct of the process, the diver-welder should be in such a position that at each given moment, the point of welding would be located above the center of the front illuminator in the diving helmet.

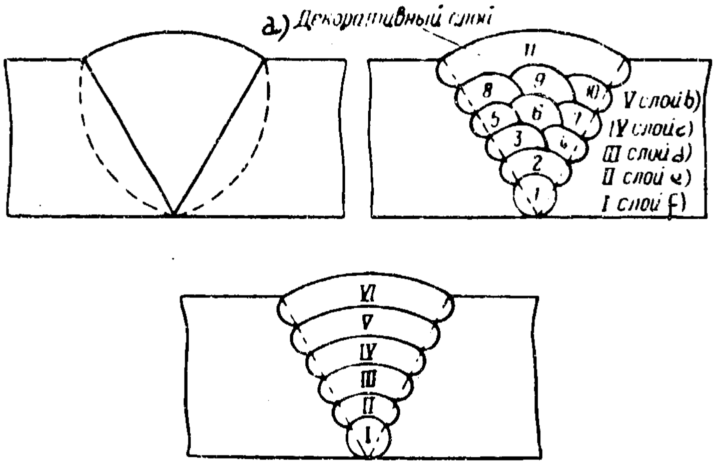


Fig. 77. Sequence of Applying Seams in Multilayered Butt-Welding (shown with numbers). Key: a) decorative layer; b) 5th layer; c) 4th layer; d) 3rd layer; e) 2nd layer; f) 1st layer.

**Welding by the bearing method**, or welding with a penetrating arc, constitutes one of the means of raising the labor productivity and the quality of the welded joints which are being made under water. The technique can be described thus: after the excitation of the arc, resting the electrode by its coating onto the product, the welder tilts it in the direction of guiding the process and performs the welding without using rocking motions.

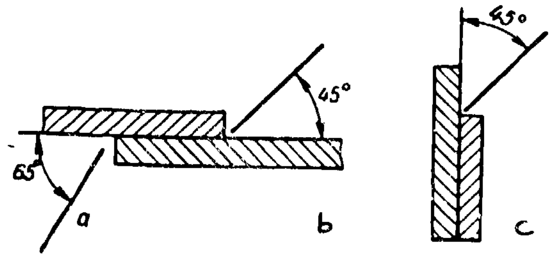


Fig. 78. Position of Electrode During Welding (with a Fillet Seam) of Lap Joints in Various Spatial Positions: a - overhead; b - downhand; and c - horizontal.

This method simplifies the work procedures, does not require high skill of the incumbent and can be performed under conditions of poor visibility. Owing to the fact that the arc seemingly /112 penetrates the interior of the base metal, the welded seam has intensified welding penetration (up to 5 mm). The arc's burning is characterized by great stability, i.e. by fewer fluctuations in the values for the current and the voltage.

Welding with use of the bearing method under water has its unique features. In the butt welding of great thicknesses, the angle of opening comprises 120°, while the blunting is 6 - 7 mm. Welding of 8 mm thick sheets is conducted without the beveling of edges, in one pass with a clearance of 0.7 - 1.2 mm, but not more than 1.5 mm. Welding with DC is conducted on reverse polarity, while with a thickness of the sheets greater than 8 - 10 mm, direct polarity is permitted.

The vertical joints are welded from above downward. The inclination angle of the electrode in respect to the joint's axis from the metal's surface during butt and lap welding or downhand tee-welding comprises 60-70° in the direction away from the axis; during butt welding, it is 90°, while during the forming of fillet welds, it is 45°. In the vertical position, the inclination angle along the seam axis comprises 40-50°, while in the direction from the seam axis during butt welding, it is 90°. During the forming of a fillet weld, it is 45°. For welding with the bearing method, use is made of the special EPO-55 electrodes (Appendix 9).

For the welding of slight thicknesses using the bearing method, we have been successful in utilizing the EPS-22 electrodes with a diameter of 4 mm. For this purpose, we use current regimes boosted by 10-15% and we select the required inclination angle depending on the actual conditions. To avoid burn-throughs during the welding of thin sheet material, the electrode is moved more quickly.

**Current Conditions and Productivity of Underwater Welding.** The approximate selection of the current strength is conducted based on the electrode's diameter, using the formula:

$$I_{CB} = Kd,$$

where K - the coefficient for underwater conditions, equalling 40-50; and d = the electrode's diameter in mm.

In the welding with the EPO-55 electrodes using the bearing method, the coefficient K = 50-60. A more precise selection of the strength of the welding current is conducted depending on the metal which is being welded, its thickness, type of joint, position of the joint in space, brand and diameter of the electrode. For the recommended current regimes according to brands of electrodes, refer to Appendix 9. /113

The submergence depth at which the welding operations are conducted has great importance. Studies have indicated that it is most advantageous to conduct the welding activities at a current force of 180-240 amps.

During the welding in a vertical position, the welding current is chosen at 10% less, and during welding in the overhead position, at 15% less, than during downhand (flat) welding.

The productivity of the underwater welding is determined by the quantity of weld metal per time unit. The productivity index is said to be the beading coefficient and is expressed in grams per ampere per hour ($\alpha_H$ = g/a•hr).

This index also has significance for evaluating the quality of the electrodes. On an average, $\alpha_H$ for underwater manual welding will fluctuate in the limits of 7-9 g/a•hr.

**Concept of the Metal Structure in a Welded Seam.** If we cut through a welded seam, file off the surface of the section, and treat it with the appropriate solution, we will discern clearly the weld metal, the zone of thermal influence and base metal.

Weld metal has a columnar structure typical for cast metal. If the weld metal has not been processed thermally or mechanically, it has relatively inferior qualities.

The zone of thermal effect, or the near-weld zone directly adjoining the cast metal of the welded joint, with a width in the limits of 3-5 mm, is characterized by the presence of a coarsely-grained structure. The heating temperature is approximately 1100-1500°C.

In the weld zone, cracks often develop, causing the rupture of the welded joint. Therefore for improving the structure of the weld zone, it is advantageous to conduct annealing. The zone of thermal influence is heterogeneous in its structure (Fig.79)—in the point of juncture with the base metal, owing to its re-crystallization during the welding, we find an improved finely-grained structure.

In the underwater conditions, as a result of the intensified cooling rates, the heat effect zone decreases in size, but the structural changes of the metal in the weld zone have more abrupt transitions. The plastic characteristics of the welded joints made under water are inferior to the characteristics of the welded joints from the same materials but made at the surface. /114

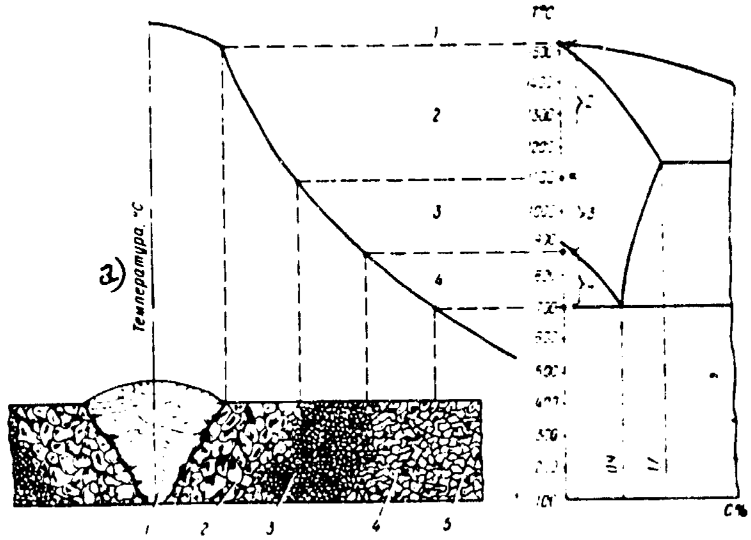


Fig. 79. Diagram of Metal Structure in Welding Zone, and Heating Temperature According to the Phase Diagram of "Iron—Carbon" Alloy: 1 - weld (cast metal; 2 - coarse grain (over-heating); 3 - fine grain (standardization); 4 - incomplete

recrystallization; and 5 - base (parent) metal. Key: a) Temperature, °C.

**Concept of Internal Stresses and Strains During Welding.** During welding, there are heated only the sectors of the sheets directly at the seam, while the remaining metal stays cold. While heating up, the metal particles tend to expand but in view of the fact that e.g. a patch being welded to the sheathing can not expand freely, but rather contracts during cooling, in it and in the welded seam, internal thermal stresses originate. These stresses can attain an appreciable value and often lead to the buckling (deformation) of the sheets, and even to the rupture of /115
the seams or of the near-weld zone. For a reduction of the internal stresses and buckling, we utilize clamping, rigid mounting, preliminary reverse strain (for instance, in the application of patches), and a fixed sequence of overlapping the seams (Fig. 80).

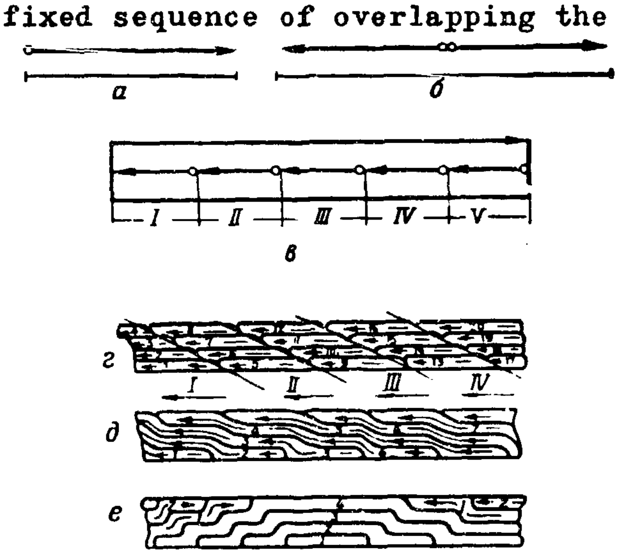


Fig. 80. Systems of Overlapping the Seams to Reduce Thermal Stresses and Buckling: a - in a pass (in case of the short seams); b - from center to ends; c - reverse stepwise; d - with successive application of layers during multilayered welding (welding by blocks); e) welding with bonding of layers; f) welding with a "hump"; the arrows show the direction of welding, while the numbers I-V and 1-20 refer to the sequence of applying the seams.

# CHAPTER 6

## UNDERWATER CUTTING OF METALS

### Section 28. Description of Metal Cutting Process and its Forms.

The cutting of metal implies the disruption of its internal bonds in a specific section or in a sector characterized by the continuity of the process. Under water, we employ all the known cutting techniques, i.e. mechanical, flame and cumulative (with a directed charge).

Mechanical cutting is utilized when its extent is slight, e.g. during the removal of a cable which has become tangled in the propeller. For this very same purpose, use can be made of the directed explosion of cumulative charges.

The flame cutting of metal is conducted with the heat developed in a layer of metal both from the burning of combustible gases, gas vapors or an electric arc with the simultaneous injection of oxygen, or without it (electric arc cutting), as well as from the burning of the metal itself.

The classification of the techniques employed in the cutting of metals and applied under water is shown in Fig. 81. The most popular method is oxy-electric cutting, while the gasoline-oxygen cutting of metals has been accepted to some extent. In isolated cases, we utilize the electric arc cutting of metals.

The nature of the oxygen cutting consists in the idea that a metal, being heated to combustion temperature (1100–1300°C for steel), acquires the ability to burn in an oxygen jet.

In underwater conditions, the continuity of the cutting process is assured only with powerful heat sources, creating its high concentration at the point of cutting.

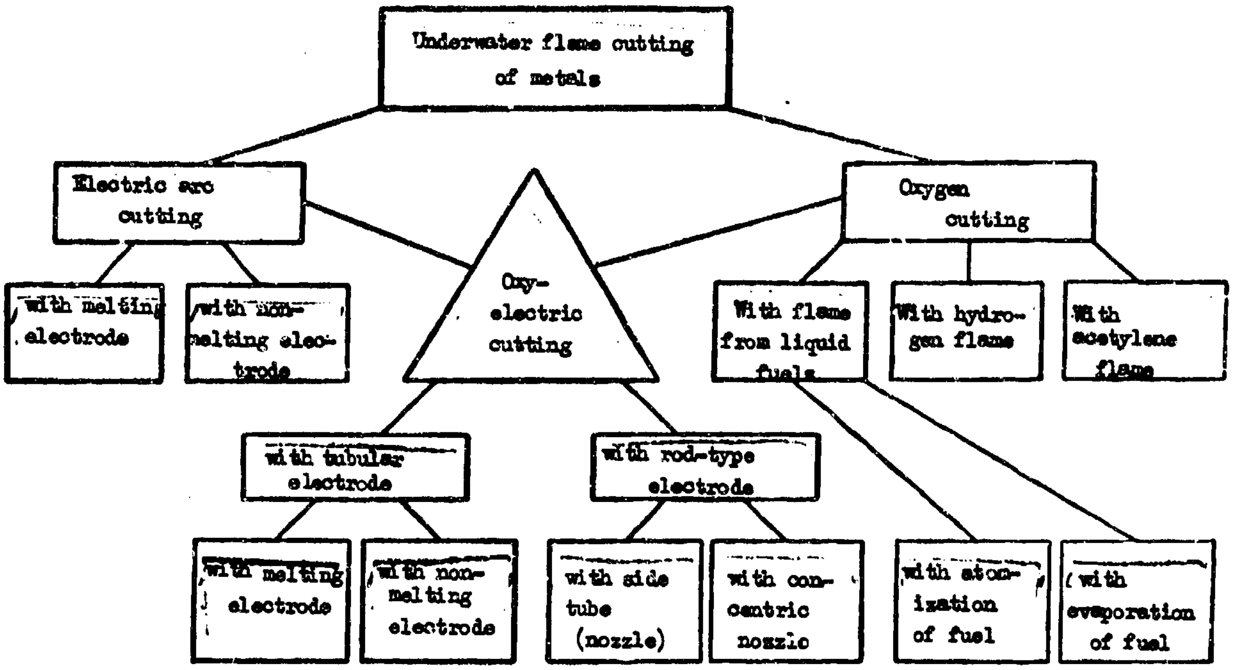


Fig. 81. Classification of Methods Used in Flame Cutting of Metals Under Water.

In this connection, the temperature of the metal's combustion should be below its melting temperature, while the metal oxides /118 (slags) are low-melting and have a melting temperature below that of the base metal.

The slags should be easy to remove from the cutting plane under the mechanical effect of the oxygen jet. Using the flame method, we can succeed in cutting only the low-carbon or the low-alloy steels, and also certain grades of special steels.

Cast iron, copper, aluminum, and stainless steel can not be cut by the oxygen method. The cutting, or more exactly the melting and burning out of these metals and alloys, are conducted only by the electric-arc technique when underwater conditions are involved.

## Section 29. Features of Flame Cutting of Metals Under Water

The conditions of cutting in water differ significantly from those of cutting in air. The density of water is 850 times greater than that of air, therefore the outflowing hot gases encounter the high resistance of the water particles. Owing to the presence of oxygen (up to 21%) in air, it maintains combustion, while water quenches a flame. The heat capacity of water is about 4 times greater than that of air, while its heat conductance exceeds that of air by almost 25 times.

These features determine the features of cutting under water—the requirement to develop a special protective bubble around the flame nucleus, and the application of increased pressures leading to greater expenditures of the gases.

The protective bubble is formed in two ways: by specially supplied compressed air or oxygen, or from the combustion products of the burning mixture. In the gasoline-oxygen cutting, use is made of the second technique of obtaining a protective bubble.

## Section 30. Fuels and Other Materials for the Oxygen-Gasoline Cutting of Metals Under Water

During the gasoline-oxygen cutting, use is made of gasoline and oxygen.

Gasoline is a light transparent (and in pure form, colorless) fluid with a typical odor. It evaporates readily and together with air forms an explosion-prone mixture. Gasoline is a mixture of hydro- /119
carbons and is obtained during the petroleum refining. For underwater cutting, we use aviation gasoline, type B-78 or B-70, leaving fewer resin deposits in the channels of the cutting tool; we also use automobile gasoline (Appendix 14).

Nonethylated gasoline is utilized for underwater cutting.

Oxygen is odorless, colorless and tasteless gas, heavier than air, does not burn, but supports combustion. At low temperatures (-183°C), it converts to a heavy blue liquid.

Oxygen is transported as a liquid in oxygen tanks (Dewar vessels), is supplied for short distances in a gaseous state through pipelines or is hauled in pressurized form in 40-liter steel tanks under a pressure of 150 atm.

To determine the amount of oxygen contained in a tank, we multiply its pressure in atmospheres times the tank's capacity in liters. Thus, in a 40-liter tank under 150 atm pressure, there is contained 6000 liters, or 6 $m^3$, of oxygen, reduced in atmospheric pressure.

Oxygen tanks are painted blue and have pressure valves and safety seals. For placement in a vertical position, the tank is rigged with a jacket underneath. On the tank's side the inscription "Oxygen" is printed with blue paint.

After the utilization of the oxygen (residual pressure of 2-3 atm), the notice "Empty" is written with chalk on the tank. The oxygen's purity affects the process of cutting the metals; therefore, for cutting we utilize oxygen which is at least 99% pure.

## Section 31. Equipment for Gasoline-Oxygen Cutting of Metals Under Water

In the Soviet Union, for the gasoline-oxygen cutting, we have developed several units of varying design. The most common is the BUPR type of installation (Fig. 82).

It consists of the gasoline cutter 4, batteries of tanks with oxygen 13, a 27 liter gasoline tank 6, a nitrogen tank 9, hoses 5 connecting the tanks through control panel 11 with the cutter and /120,121
directly with the gasoline tank. Of the three available hoses with a length of 50 m each, two rubberized fiber ones having a diameter of 9.5 X 18 mm serve for feeding the heating and cutting oxygen, and one Durite hose with a diameter of 6 X 14 mm is used for supplying the gasoline.

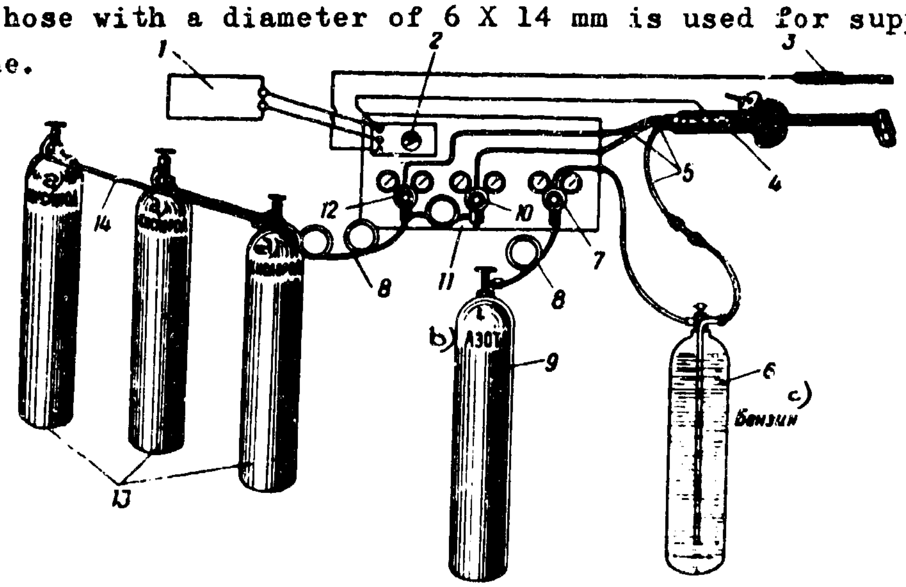

Fig. 82. Assembly System for BUPR installation for Underwater Gasoline Oxygen Cutting: 1 - battery; 2 - voltmeter; 3 - ignition; 4 - cutter; 5 - hoses; 6 - tank with gasoline; 7 - reducing valve for nitrogen; 8 - coils; 9 - tank containing nitrogen; 10 - reducing valve for heating oxygen; 11 - control panel; 12 - reducing valve for cutting oxygen; 13 - oxygen tank; 14 - collector (or ramp in the case of a large sampling of gas). Key: a) oxygen; b) nitrogen; and c) gasoline.

On control panel 11, three reducing valves are mounted: two for the oxygen—for the heating oxygen 10 and cutting oxygen 12, and one for oxygen 7, which is fed to the gasoline tank 6.

For igniting the cutter under underwater conditions, on the inside of the cover, there is the electric igniter 3 connected to terminals on control panel 11. The ignition system is powered from storage battery 1, type 10NKN-22M or 10NKN-45 with voltage of 12 v.

The electric ignition device is connected to the negative terminal of the battery while positive current is fed to the cutter. For monitoring the battery's voltage, voltmeter 2 is mounted on the control panel.

For connecting the tanks to the control panel, there are the coils 8, usually made of red copper tubing; for connecting the tanks to the battery, use is made of collectors 14, while in the performance of large scales of work—oxygen ramps are employed.

The unit also contains a gasoline filter, spare parts and tools for assembling and disassembling the facility.

The gasoline cutter is the key unit in the installation for underwater cutting, establishing its operational and technological characteristics. The gasoline cutter of the BUPR installation (Fig. 83) functions on the principle of the atomization of gasoline rather than its evaporation. It consists of the head 1, the connecting tubes 2, and handle 5. Three valves are mounted on the cutter handle—one (coded 8) for the heating oxygen, one (coded 4) for the cutting oxygen, and one (coded 3) for the gasoline supply.

With these valves, the diver adjusts the supply of the gases during the cutting, and while controlling the process. For connecting the hoses, use is made of sleeve 7 fitted with adapters, and the head is connected with the cutter by the intermediate pieces, 9.

The cross section of the BUPR head is depicted in Fig. 84. The head functions as follows: jets of gasoline and heating oxygen which are supplied via tubes 2 and 4 and pass along the channels of atomizer 7, upon emerging from it (being directed at an angle to one another) (the outlet openings 10 and 12) collide in mixing chamber 11. The gasoline jets are broken into droplets and, striking the round surface of mixing chamber 11, become converted to the finest mist. /122

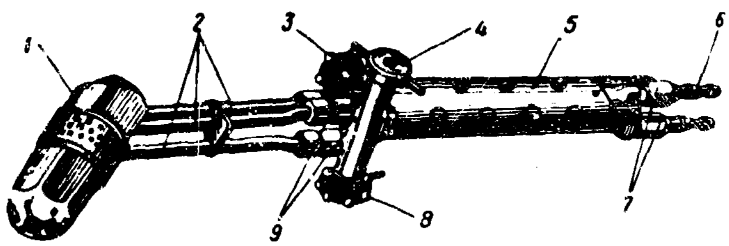


Fig. 83. Gasoline Cutter of the BUPR Installation: 1 - head; 2 - connecting tubes; 3 - gasoline supply valve; 4 - feed valve to cutting oxygen; 5 - casing of cutter (handle); 7 - sleeve fitted with adapters 6 for connecting the hoses; 8 - valve for providing the heating oxygen; 9 - intermediate pieces for connecting the head with the cutter frame.

Acquiring a surface of ever-increasing area and located in the path of the powerful gas jet, this gasoline vapor becomes intensively evaporated and, moving along with the oxygen, forms a hot mixture consisting of vapors and foggy liquid particles of gasoline and oxygen. The hot mixture, escaping under pressure from the central hole in the nozzle 9, is ignited by an open flame or by an electric lighting unit. At this time, a strong flame develops, emitting a typical whistling noise.

With the proper gas/oxygen ratio, the nucleus of the flame should be located near the outer edge of the nozzle outlet 9;

by the same token, the rear part of the nucleus is protected by the walls of nozzle 9 and this provides stability to the flame in the water.

The pressure in the chamber becomes fairly high and in its turn, this requires stepped-up pressures for feeding the gasoline and oxygen.

The cutting oxygen is fed through tube 3 and passes along the central channel 8 of atomizer 7. In distinction from the other designs of non-evaporative-type gas cutters, the feeding of the cutting oxygen into the BUPR unit occurs independently; in this /123
manner, it does not influence the delivery of the heating oxygen.

As a result of the operation, in the cutter's inside channels a resinous incrustation gradually builds up (polymerization products), capable of putting the cutter out of working order; therefore, it should be cleaned periodically.

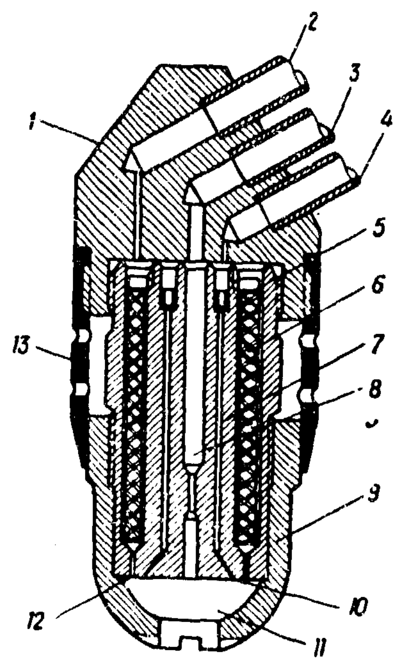


Fig. 84. Cross Section of Head to BUPR Cutter: 1 - frame; 2 - gasoline supply pipe; 3 - pipe for delivering the cutting oxygen;;4 - pipe for heating oxygen; 5 - wire washer; 6 - gasoline-control rods; 7 - atomizer; 8 - central channel; 9 - nozzle; 10 - outlet holes for oxygen; 11 - mixing chamber; 12 - outlet openings (orifices) for gasoline; and 13 - cooling ring.

For washing the cutter, we recommend a liquid with the following composition (1 gram per liter of water): liquid glass--8.5 grams; soda ($Na_2CO_3$)--18.5 grams; and green soap--10 grams.

The control panel, cutter, electric ignition unit, coils and ZIP are packed in a case made of thin-sheet steel.

The weight of the device including the storage battery, the gasoline tank and the hoses (but without the nitrogen and oxygen tanks) amounts to 170 kg.

The hoses of the BUPR device (GOST 6286-60) are covered with a metallic wire braiding. This permits the performance of the tasks at depths ranging from 30-40 m.

## Section 32. Technique of Underwater Gasoline-Oxygen Cutting and Working With the BUPR Installation

Before assembling the device, it is necessary to verify the proper conditions of its units, and to clean the parts of the cutter head with a clean dry napkin. The assembly of the BUPR device is /124
performed according to the procedure shown in Fig. 82. After the removal of the caps and seals from the tanks, we run a one-second clearing (scavenging) of the valves to remove the dust and dirt which had entered the outlet.

In order that they would be stationary and would have a certain slope, the oxygen tanks are mounted on supports or are installed vertically and anchored. The gasoline tank is set up only vertically and is connected by a rubber hose through the control panel with the nitrogen tank.

The entire system is checked for airtightness of pressure deliveries (6-8 atm) and by wetting the points of connection with soapy water.

The blowing through of the gas line and checking it for a tight seal are conducted only with nitrogen, in order to avoid an explosion. The axssembled gas cutter is also check for vacuum seal. The cutter is then checked for proper burning--the combustible mixture is ignited and the flame is adjusted. However, one must never hold the cutter in the air for more than 5 seconds since the head could melt and the gasoline cutter would go out of commission.

In lighting the flame, we first open the heating oxygen valve and then the gasoline valve. In the air, the mixture is ignited by the open flame. For this purpose, under water we utilize an ignition device wherein the ignition system is activated and with a striking movement on the nozzle (with the head downward), contacts are made with the igniter. The resulting sparks ignite the combustible mixture.

During work at a slight depth, e.g. at the side of the ship, the cutter is supplied to the diver after it has been lit, but in this connection caution is observed and the diver is warned in advance.

After the diver has adjusted the flame and provided it with a slight excess of oxygen, the cutter is placed by the nozzle (or is pressed into contact, depending on the spatial position of the cutter) on the object which is being cut, perpendicularly to the surface to be cut. We recommend that the cutting be done from the edge of the sheet.

After heating the metal for 3-6 seconds, without removing the cutter from the point of the heating, with an abrupt, powerful turn of the valve knob, the cutting oxygen is supplied (the left valve is /125
opened).

The beginning of the cutting is typified by the ejection, from under the nozzle, of the molten combustion products of the metal and by a powerful luminescence. After the metal has been cut through, only the glow will remain on the surface while a shower of sparks will depart behind the rear side of the sheet which is being cut. After the metal has been cut for its entire thickness, the diver begins to move the cutter head with a sliding motion along the line of cutting, seeing to it that the glowing of the metal under the nozzle does not weaken.

With the cessation of the metal's burning, the delivery of cutting oxygen is shut off, the cutter is returned to the place where the metal cutting was finished; the diver again performs the heating and the cutting process is renewed.

In cutting metal of great thickness, increased pressure is applied while the supply of the cutting oxygen (in the process of the initial cutting of the metal) is gradually stepped up for the entire thickness until a through cut is developed.

It is necessary to follow the process of cutting the profiles of various thickness, with particular attention observing the through cutting of the metal and performing a timely adjustment of the cutting oxygen supply. At all times, the diver's left hand should be resting on the valve knob.

The cutting of bunches (packets) is especially complex. In cutting bunches with one pass, the pressure of the cutting oxygen must be increased by 15-20%. If the distance between the elements of the bunch is great and the heat being developed during the cutting for heating the sectors of the underlying element to the combustion temperature is insufficient, each element in the bunch is cut separately according to the system shown in Fig. 85.

For obtaining a straight clean cut, we recommend that the metal be brightened from the opposite side. The marking of the cutting lines is done with chalk boiled in grease. Guide strips or angle plates are sometimes placed along the cut; the area to be cut should first be cleaned off.

The conditions (regimes) for the gasoline-oxygen cutting /126
with the aid of the BUPR device and the technical cost data are listed in Appendix 15.

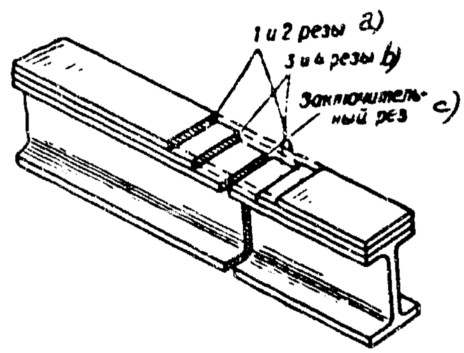


Fig. 85. Steps for Cutting a Set of Items by Units. Key: a) 1st and 2nd cuts; b) 3rd and 4th cuts; and c) Final cut.

During operation in the depths and the cutting of great thicknesses, owing to the considerable sampling of the gases, the reducing valves can freeze; we therefore recommend heating them with boiling water or utilizing the closed type of electric heaters. At the completion of the cutting process and upon extinguishing the cutter, we first close the cutting oxygen valve, then the gas valve and the heating oxygen valve.

During interruptions in the work under water, to avoid soiling the cutter outlets with sand or mud, the cutter must never be placed on the bottom. Only a copper wire may be used for cleaning the holes in the evaporator and the head.

After the completion of the work, at the diver's command the oxygen and gas supply is cut off, the cutter is raised upward and the installation is disassembled.

After the work, the hoses are unhooked and are coiled for storage in containers. The gasoline is drained from the gas tank. After each cutting operation, the cutter head is disassembled, and all conduits and orifices are rinsed with clean gasoline. The resinous crust which has formed is removed. During prolonged interruptions in work, the cutter head is stored in assembled form.

## Section 33. Electric-Arc Cutting of Metals Under Water /127

The nature of electric-arc cutting consists in the idea that under the effect of intensively concentrated heat, the metal is melted and partly burned.

In the underwater conditions, electric-arc cutting can be accomplished with the same equipment as is utilized during the welding. In the event that the power source is insufficient, the assemblies are connected in-parallel. The electric-arc cutting is conducted with alternating or direct current of direct polarity and can be achieved both with metallic and nonmetallic electrodes. The quality of cutting with the electric-arc technique is low and the output is slight. Under submerged conditions, the electric-arc cutting is employed only in special cases, e.g. during the cutting of bent blades or a bronze or cast-iron propeller.

The possibility of performing the cutting of metal independently of its properties and chemical composition is a unique advantage possessed by electric-arc cutting vis-à-vis the other fire-cutting procedures.

Just as in the gasoline cutting, we recommend that the electric-arc cutting be started from the edge of the metal sheet; however, if this is impossible, a hole is first burned. For this purpose, after the arc's excitation, the electrode is placed perpendicularly to the object's surface and is pressed lightly against it. In proportion to the penetration of the electrode into the welding pool, the liquid molten metal is pressed out onto the surface, forming a bead around the opening (Fig. 86). The hole which is burned through turns out to be 2-3 mm larger than the electrode's diameter (including the coating).

After the hole has been made, we again activate the arc and the electrode is tipped in a direction opposite to the direction of the cut (Fig. 87a). Pressing on the electrode, the diver forces it to slide downward along the edge. At this time, the metal melts, and the coating shield developing on the electrode helps in the removal of the liquid metal from the cavity of the cut. Bringing the electrode to the lower edge of the sheet, the diver-cutter (without interrupting the arc) quickly raises the electrode to the top edge and recommences the process of the melting and mechanical extrusion of the metal (Fig. 87b). In case of cutting from the edge, the process begins with the melting of the lower corner and a gradual transition to the upper surface. /128

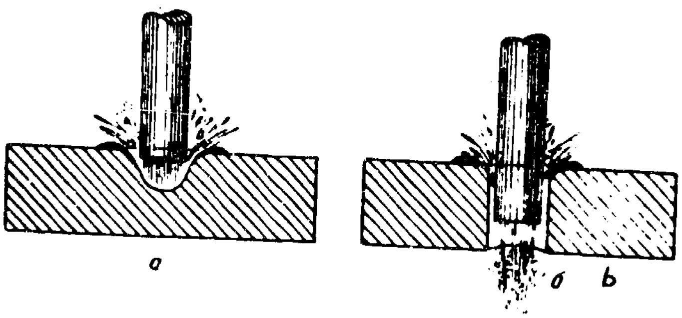


Fig. 86. Burning a Hole Through Metal with an Arc.: a - beginning of cut; and b - completion of the cut.

Just as for welding, the current regimes for the electric-arc cutting are chosen on the basis of the formula $I_{CB} = Kd$, but with $K = 60-80$. In special instances, e.g. during the cutting of thick parts of brass or bronze when underwater conditions are involved, the current strength is intensified; however, in the utilization of electrodes with a diameter of 5 mm, it should not exceed 500 amps.

The composition of the electrodes' coating for underwater cutting is given in Appendix 8; the coating is simplier since it requires only a stable burning of the arc; however, the quality of the coating should comply with the same requirements as in the case of the electrodes used for the underwater welding.

As rods for the underwater electric-arc cutting, we utilize the electric welding wire (GOST 2246-60) (see Appendix 7), and also low-carbon wire of any brand (e.g. rolled wire).

The consumption of electrodes during cutting is appreciably greater than during welding. Owing to the rapid burning of the electrode, one must often interrupt the cutting process; therefore, the productivity of the process is fairly low. This comprises one of the shortcomings of the electric-arc cutting technique.

For electric-cutting under water, we utilize the same tools and devices as during the underwater welding. Data on the productivity of the electric-arc cutting of steel under water are presented in Appendix 16.

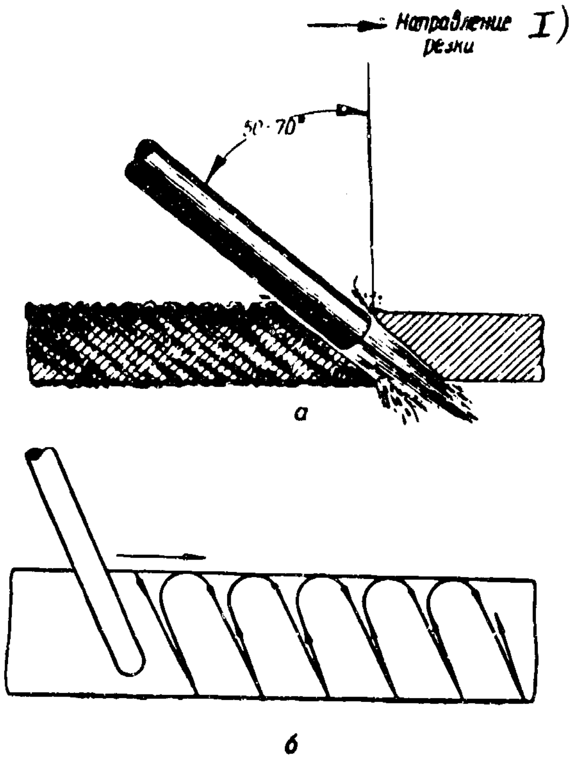


Fig. 87. System of Using the Electrode in the Electric-Arc Cutting of Metal in the Downhand (Flat) Position: a - position of electrode; and b - pattern of moving the electrode. Key: I) Direction of cut.

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Section 34. Electric-Oxygen Cutting of Metals Under Water

The process of electric-oxygen cutting consists in the idea that during the excitation of the arc by the electrode, the surface sectors of the metal (which are blown upon by the jet of oxygen fed to the arc) become melted. Thus, the oxygen comes into contact with the solid lower-lying sections of metal heated to the ignition point; interacting with them, it oxidizes the metal and heats the subjacent (underlying) and contiguous sections.

The oxygen jet not only oxidizes (burns) the metal; at the same time, it mechanically blows from the cutting cavity the slag and molten metal which have formed during the cutting. The cutting process thus becomes a continuous one. /130

The cutting is performed with tubular electrodes covered with a special coating. Use can be made of the metallic, carbon (carbon-graphite) and ceramic (carborundum) tubes.

The carborundum and metal-ceramic electrodes have increased strength. The length of a tube is 250-300 mm, the diameter of the carborundum tube is 15 mm, while that of the metal-ceramic tube is 8-10 mm. A metal coating is applied to these tubes and this is covered with a stabilizing mineral coating.

We utilize the EPR-1 electrodes for the underwater electric-oxygen cutting. These electrodes with a length of 350 mm (Fig. 88) are made from thick-walled seamless tubing with an outside diameter of 7 mm and an inside diameter of 2.5 mm (GOST 1050-60, Appendix 17). Just as for welding, the tubular electrodes have a special coating (App. 8). Before cutting, the diver marksout the area and places the guide strips in position.

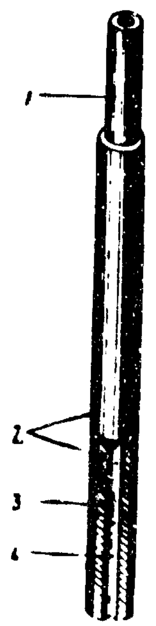



Fig. 88. Metal Tubular Electrode for Underwater Electric-Oxygen Cutting: 1 - bared section; 2 - coating; 3 - thick-walled steel tube; and 4 - channel for delivery of oxygen.

The oxy-electric cutting starts with the delivery of oxygen and then the arc is activated. If one activates the arc and then supplies the oxygen, splashes of molten metal and slag get into the electrode channel, reach the sealing to the holder head, and this often leads to the burning out of the linings and the breakdown of the holder.

Investigations have shown that a modified system for the beginning of the oxy-electric cutting excludes entirely the entrance of slag and metal bits into the electrode's channel and the holder's head, and thereby markedly increases its stability.

After the current has been turned on at the diver's command, /131
he presses the lever to the oxygen valve, verifies that oxygen is coming through, then touches (with the electrode) the metal to be cut, and activates the arc.

Maintaining the constancy of the arc's burning, in proportion to the burning of the electrode, the diver lowers his hand and moves the electrode along the cutting line with an inclination of 10-15$^{\circ}$ from the vertical in a direction opposite to the cutting direction.

During the cutting of thin sheets, the electrode is moved along the marked cutting line over the metal's surface. During the cutting of thick sheets, the electrode is plunged into the molten metal as is done during the electric-arc cutting.

During the cutting, it is necessary to verify that the arc is burning constantly, and otherwise the process will cease. At cessation of the cutting, one should first cut off the arc and then shut off the oxygen supply. If these steps are reversed, slag and metal bits will get into the channel of the tubular electrode and foul it; they could also cause the burning of the head (of the paronitic linings) and put the electrode holder out of order.

The productivity of the oxy-electric cutting is 3-4 times higher than that of the electric-arc cutting, and has a higher quality. The cutting rate is the least in the downhand position, while during vertical cutting, it increases; this is explained in terms of the uneven utilization of the oxygen which is being delivered. The most favorable conditions for the utilization of oxygen exist during cutting in the overhead position, but the inconvenience of the work and the flowing of metal oxides into the cutting cavity reduce the speed. Cutting in the vertical position is conducted from above downward, while in the horizontal and vertical planes, it is usually done from right to left.

The regimes (sets of conditions) for the oxy-electric cutting are presented in App. 18.

Tools and Devices for the Underwater Oxy-Electric Cutting of Metals. For the oxy-electric cutting, we utilize the same welding station as during the electric-arc welding, with the exception of the electrode holder.

In the oxy-electric cutting, we assemble the installation (Fig. 89), consisting of the welding generator (subassembly) 3, the tank 1 (or battery of tanks) with oxygen, of a special electrode holder 4, a reducing valve 2, plus cables and hoses of the appropriate length. The same welding generators are utilized as during the underwater welding. The reducing valves, hoses and tanks are the same as are used in the gasoline-oxygen cutting. /132

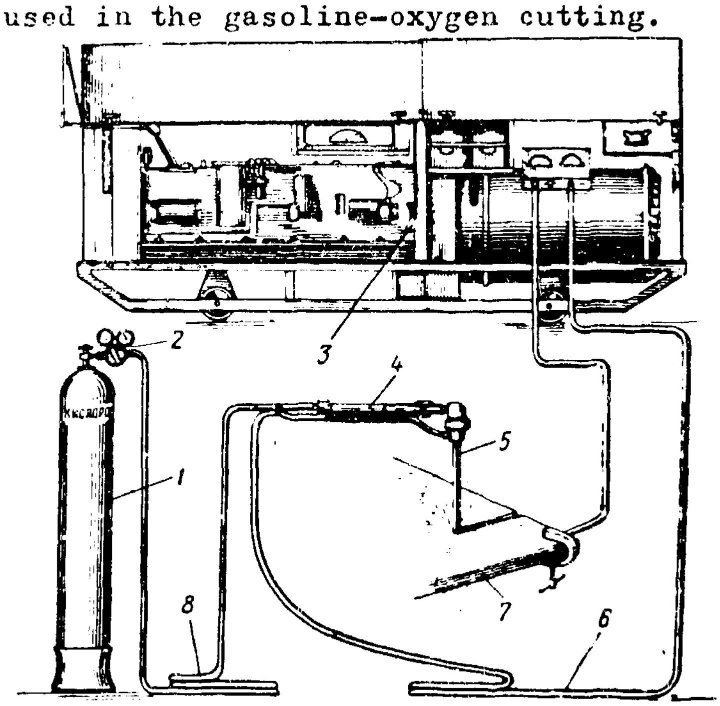


Fig. 89. Arrangement for Underwater Oxy-Electric Cutting of Metal: 1 - tank containing oxygen; 2 - reducing valve; 3 - welding subassembly; 4 - electrode holder; 5 - electrode; 6 - welding cable; 7 - object being cut; and 8 - oxygen hose.

The electrode holder combines the current supply and the delivery of oxygen, with the aid of which the cutter operator controls the cutting process. The type EKD-4 (Fig. 90) electrode holder has become most popular. It consists of head 14, frame 1, oxygen valve 3 with a lever, and of handle 4 with a fitting for the attachment of welding cable 6. For improved waterproofing and electrical insulation, head 14 of the electrode holder is installed /133 in the textolite cup 12, having holes for the passage of the electrode and the placement of the welding cable 6.

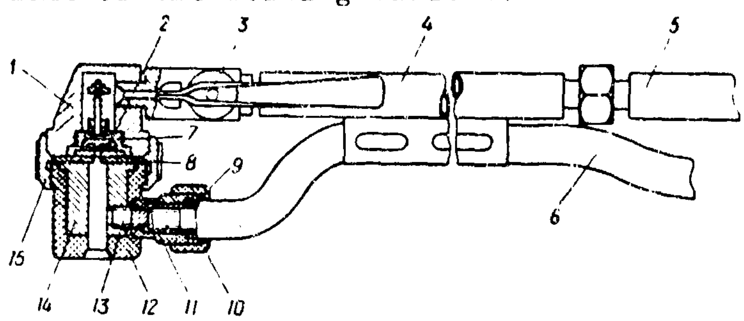



Fig. 90. EKD-4 Electrode Holder: 1 - frame; 2 - nonreturn valve; 3 - oxygen valve with lever; 4 - handle with fitting; 5 - oxygen hose; 6 - current conducting (welding) cable; 7 - safety valve; 8 - paronitic lining; 9 - rubber lining; 10 - coupling nut; 11 - textolite bushing; 12 - textolite cup; 13 - threaded connection with textolite bushing; 14 - head; and 15 - coupling nut.

The electrode holder should provide a rapid replacement of the electrodes during the work, and should exclude the leakage of oxygen.

A feature of the EKD-4 electrode holder is the presence in its frame 1 of safety valve 7, protecting the head and hose 5 from the so-called "reverse impact" i.e. the phenomenon when (owing to the difference in the pressures in the ambient medium and in the electrode's channel), the molten metal tends to flow upward along the tubular electrode and to penetrate into the electrode holder's head. As a result the linings and sometimes the entire head burn out. In order that the fire would be contained, in safety valve 7 we place the nonreturn valve 2. At an increase in the external pressure, the head of valve 2 closes the channel and prevents the flame from spreading any further.

Head 14 is fastened to frame 1 by the coupling nut 15. On the side at head 14, the threaded connection 13 is provided for linkage to the holder of welding cable 6. The fastening of cable 6 is realized with the aid of the textolite bushing 11 and the /134 coupling nut 10, placed on the rubber lining 9.

The oxygen hose 5 is placed on the adapter of handle 4, representing a brass tube with a fitting soldered on for the welding (current-conducting) cable 6. The electrode is inserted in the blind hole of head 14 as far as it will go, and is anchored with a screw clamp (not visible in Fig. 90).

For controlling the supply of oxygen to electrode holder EKD-4, provision is made for the oxygen valve 3 fitted with a lever. The lever is mounted on the left, therefore it is easy to control the starting of the oxygen, exerting pressure with the right-hand thumb, without changing the hand's position at this time.

During the work with the holder, it is necessary to monitor the waterproofing and electrical insulation of contact 13, tightness of the oxygen supply line and head, and to observe the proper technique for the lighting and extinguishing of the arc.

Among the possible malfunctions of the holder, we include the lack of oxygen supply, usually associated with the plugging of the channel of the electrode or the holder's head, and the absence of electric current supply in case of poor contact of the cable with the holder's head.

The elimination of these malfunctions, just as the replacement of the sealing linings, does not present any difficulties; if the holder breaks down during the activity of the diver under water, the holder should be fed upward, after the diver has turned in a report by telephone on what has taken place. At this time, the welding current is cut off.

The procedure for assembling and disassembling the setup is similar to the sequence involved in the assembly and disassembly of the unit utilized for the gasoline-oxygen cutting. Prior to the assembly of the installation, one verifies the proper conditions of all its units. This is required for the continuous (normal) operation of the diver under water. The assembly of the equipment begins with the assembly of the battery of oxygen tanks (in case of a large volume of operations), followed by the removal of the caps and seals from the valves of the oxygen tanks, and a one-second clearing of the valves.

The tanks are connected to the battery. If the scope of work is small, one tank is taken, to which a reducing valve has been attached. After the mounting of the reducing valve on the tank, we also perform a one-second clearing of the reducing valve. For this purpose, the valve is opened while the adjusting screw of the valve is turn clockwise. At this time, the valve is opened and the oxygen /135
moves outward, entraining with it the dust and dirt which has seeped into the outlet fitting of the reducing valve. The oxygen hose is then connected; by opening the valve of the tank and of the reducer, this hose is also subjected to a one-second clearing.

After the blowing through, the oxygen hose is attached to the adapter of the EKD-4 electrode holder. The electrode holder is subjected to scavenging and is checked for its seal, i.e. a working pressure is applied to it; with closed valve and inserted electrode, it is lowered into a bucket filled with water. Then in the bucket containing the water, the lever is pressed, but at the same time one presses a finger on the end of the tubular electrode. In this case also, there should not be any lateral leakage of oxygen through the recess in the holder's head. If oxygen leakage should be detected, we replace the linings in the electrode holder, and increase the tightness of the head.

After checking out the entire main oxygen line, we fasten the welding cable to the electrode holder; the cable is connected by its second end to the minus terminal on the Born panel of the welding installation. The second cable is connected to the plus terminal and is supplied directly to the object which is being cut. Before lowering the second cable into the water, we check the electric circuit at the surface by starting the installation and firing the arc.

Only after the verification of the proper condition of the entire setup do we lower the diver into the water and send to him the electrode holder and the second end of the welding cable, which the diver connects to the object to be cut. These items are ordinarily sent down after the diver had already arrived at his work site and has issued the appropriate order. During the lowering of the cable and the electrode holder, the welding circuit should be deactivated (cut off).

During the work, the diver-cutter should have a reserve stock of electrodes and an auxiliary tool.

## CHAPTER 7 /136

## AUTOMATION OF UNDERWATER WELDING AND CUTTING

### Section 35. **Semiautomatic Welding Under Water**

Currently studies are in progress on automating the process of underwater welding, in order to increase the productivity and to eliminate the individual influence of the diver-welder on the quality of the welded joint. Use has been made of a series of techniques, and only the appearance of the method of automatic welding in an envelope of carbon dioxide has permitted us to find the proper approach for automating the welding process under water.

At first it appeared that the introduction of carbon dioxide would yield a positive result, since its presence in the arc zone altered the relationship of the components in the gaseous phase of the steam-gas bubble, lowered the partial pressure of hydrogen, and thereby reduced its solubility in metal. It is known that hydrogen decreases the plastic cheracteristics of metal and makes it brittle; therefore, a reduction of its content in the metal is always desirable.

The effect of the oxidizing medium on the molten metal, being developed in the presence of carbon dioxide, could be compensated by the use of wire with an increased content of deoxidizing agents, namely silicon and manganese.

However, as it was then explained, the application of carbon dioxide during semiautomatic welding under water causes pore formation in the weld metal and introduced technical difficulties concealing the arc and interfering with the observation of the advancement of the process. In connection with this, we applied another method of welding with an open fine electrode wire un- /137
protected by the arc, with high current densities.

Experience showed that the welded joints made with an open arc surpass in quality the joints made with supply of carbon dioxide to the arc; there is no porosity, the data resulting from the mechanical tests are more stable (have a narrower range of values), especially in respect to plastic characteristics. It became possible to develop permanently strong joints in the overhead position.

Semiautomatic welding is conducted without swinging motions, with the application chiefly of an electrode wire with diameter of 1.2 mm, brand Sv-08G2s, complying with GOST 2246-60. Welding in the vertical position is performed from above downward. Polarity is adopted as reverse, i.e. the minus is connected to the object while the plus is connected to the electrode. With the semiautomatic device, we can weld steel with a thickness of 4 mm and more. The productivity of semiautomatic welding under water is about 7-8 times higher than during the underwater manual welding.

The control of activating the welding current and of the wire deliveries is accomplished from a distance by the diver-welder under water. The data characterizing the process of semiautomatic underwater welding with an open unshielded arc are listed in Appendixes 19 and 20.

## Section 36. Semiautomatic Oxy-Electric Cutting Under Water

In spite of the significant advances made in the electric-arc cutting and particularly in the oxy-electric cutting by hand with a tubular electrode, this process will remain low in output.

The suggestion has been made to mechanize the process of cutting under water, utilizing for this purpose the semiautomatic devide for underwater welding with a fine electrode wire and the delivery of an oxygen jet at a certain angle to the direction of the electrode in the cutting plane.

It was established that the cutting regime becomes optimal when the point of encounter of the oxygen jet and the electrode's direction coincide with the bottom of the welding pool. In this connection, the oxidizing ability of the cutting jet of oxygen is employed most fully.

The technological angle $\alpha = 18^{\circ}$ corresponds to this condition at the prescribed design dimensions of the cutting attachment on the semiautomatic device. At the outlet, the nozzle has a round channel with a length ranging from 2 to 3 d of the outlet opening, at a total length of not less than 5 diameters of the outlet opening. /138

Tests have demonstrated that the nozzle selected on the basis of the conditions cited and provided with a cylindrical channel assures a high quality of cutting under water. Based on the studies accomplished, we have developed a design of a general-purpose semiautomatic device for welding and cutting under water. The process is accomplished with reverse polarity. With the aid of this attachment, we succeeded in cutting solid sections with a thickness up to 40 mm, however the semiautomatic device operates reliably in the limits of thicknesses up to 25 mm. The cutting of sets (e.g. of the ship framing) is conducted by the method of successive dismemberment--by elements of the set individually.

All those materials which are subjected to cutting with oxygen are also subjected to semiautomatic oxy-electric cutting under water. Based on the data from the measurement of machine time, the productivity of the semiautomatic cutting is 8-9 times higher than that of the manual cutting.

The cut made under water proves to be narrow, clean, without bumps or arches, i.e. it resembles a cut made by hand with a kerosene-type cutter at the surface. The preliminary data on the regimes and productivity of the semiautomatic cutting at depths up to 10 meters have been listed in App. 21.

## Section 37. Semiautomatic Device for Underwater Welding and Cutting

For underwater semiautomatic welding with and without the supply of carbon dioxide to the arc, and also for the underwater semiautomatic oxy-electric cutting, use is made of the PPSR-300-2 semiautomatic device of the VNIIESO design (Fig. 91).

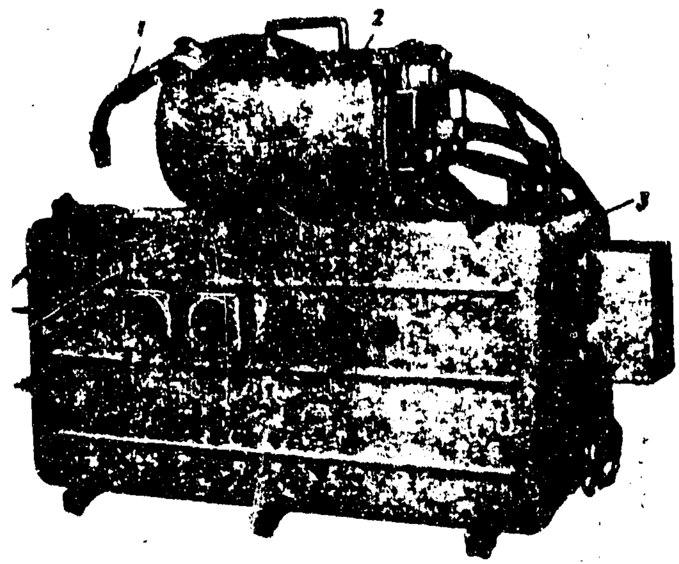



Fig. 91. Semiautomatic Device for Underwater Welding and Cutting (Type PPSR-300-2): 1 - head (torch) with lever for remote-controlled activation of welding current and supply of electrode wire; 2 - sealed tank with mechanism for supplying the wire; and 3 - control cabinet.

**Arrangement of Semiautomatic Machine for Underwater Welding and Cutting.** The semiautomatic machine (Fig. 92) consists of the following basic units: a special power supply to arc 1, a control cabinet 2, a feed mechanism with a supply of electrode wire 1.2-1.6 mm in diameter in a case, enclosed in a round sealed frame (tank) 13 submerged in the water, the head 16 of the semiautomatic device, hoses 10 and 11 for supplying the gases, and cables 18. /139

The control cabinet (Fig. 93) is mounted permanently on the ship near the divers' (welding) station (is attached to the bulkhead). The control cabinet can be connected to the DC network with a voltage of 110 or 220 v. Industry is also manufacturing control cabinets for operating on 200 v alternating current. Through the control cabinet, we accomplish the complete control of the semiautomatic device's operation, i.e. the delivery of the electrode wire, supply of oxygen during cutting, and the connection or disconnection of the welding current. In distinction from

similar installations for welding in carbon dioxide e.g. the ADPG-500 or the PDPG-300, the control of the deliveries of the carbon dioxide (or of air during cutting) is not accomplished, since in the given case, the carbon dioxide performs an additional function, namely /140
the sealing of the submerged units of the semiautomatic machine, including the tank and the head, and also the hoses. The gas is fed "directly", moreover its starting begins from the first moment of the semiautomatic device's submergence in the water.

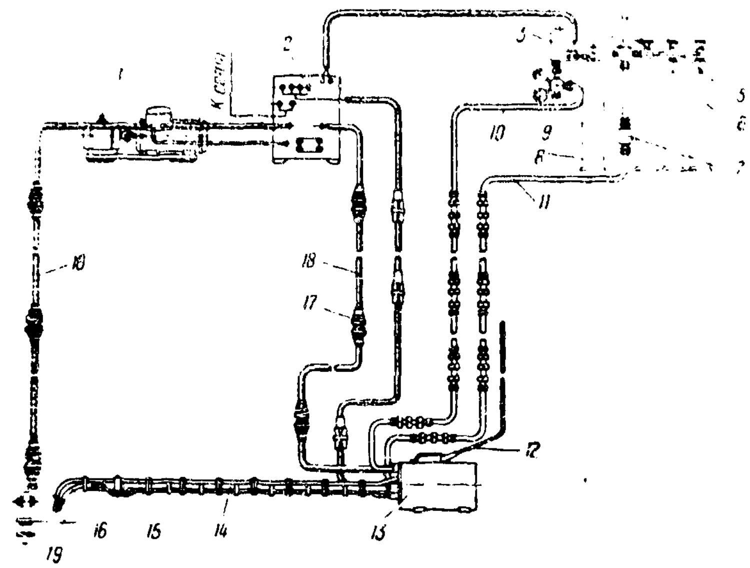



Fig. 92. Assembly Diagram of Semiautomatic Machine for Underwater Welding and Cutting: 1 - source of power supply; 2 - cabinet for controlling the machine; 3 - electrode heater; 4 - oxygen reducing valve; 5 - collector; 6 - tanks containing oxygen; 7 - oxygen valve; 8 - tank containing carbon dioxide; 9 -carbon dioxide reducing valve; 10 - hose for feeding the carbon dioxide; 11 - hose for supplying the oxygen; 12 - cable for suspending the tank containing the delivery mechanism during submergence in water; 13 - wire supply mechanism in sealed tank (frame); 14 - special hose-cable; 15 - oxygen hose; 16 - head (burner) of semiautomatic device; 17 - connecting cable sleeves; 18 - welding cable; and 19 - object (sheating of ship). Key: a) to network.

In the control cabinet, there are mounted the electric drive motor (ДП) 15, which runs two generators, i.e. generator (ГВЦ), supplying the auxiliary circuits with current, assuring the functioning

of the system (of relays), i.e. the connection and disconnection of the welding contractor 10 and of the oxygen valve (KK) 12, and also of other small parts, including the indicator bulb etc. The other generator which the motor runs is the ГДП generator, i.e. /141,142
the generator to the motor 17 for supplying the electrode wire. In addition, the cabinet contains the measuring instruments 4,5, a regulating device 3 for feeding the wire, representing a potentiometric rheostat connected to the circuit to the field winding (magnet coil) of generator ГДП17, the pushbutton welding switch KC (not visible in the figure), and the cutoff switch BK 2 for providing current to oxygen valve 12.

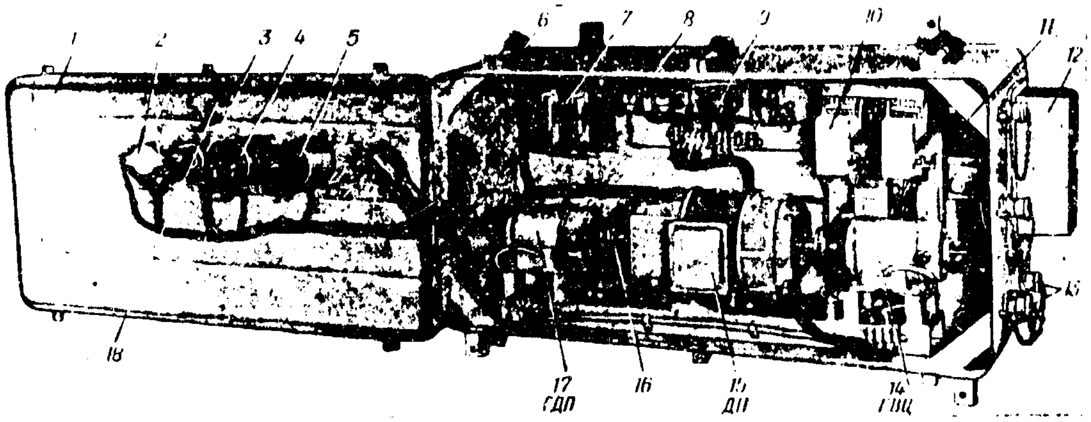



Fig. 93. Control Cabinet of Semiautomatic Machine: 1 - front panel (cover) of cabinet; 2 - cutoff switch BK of oxygen valve; 3 - device for adjusting the supply of wire; 4 - ammeter; 5 - voltmeter; 6 - coupling clamp; 7 - fuses; 8 - frame of cabinet; 9 - unit of relays; 10 - contactor (main starter); 11 - shunt; 12 - oxygen valve KK; 13 - plug-in connections for linking the welding cable and the leads to the control circuits; 14 - ГВЦ= generator to the control circuits (auxiliary); 15 - ДП - electric drive motor; 16 - clutch; 17 - ГДП-generator of motor for supplying wire; and 18 - indicator bulb.

For the connection of the welding cable and of the leads from the control circuits of the semiautomatic machine's submerged units, special outlets with plug-in sockets 13 are provided in the control cabinet. In addition, on the front panel 1 of the control cabinet, a toggle switch is provided for switching the system over from welding to cutting operations. The control cabinet is made in a spray-protected design and is adapted for operation under shipyard conditions. The dimensions of the cabinet are 1330 X 498 X 610 mm and it weighs 120 kg.

The wire-feeding mechanism provides the forced delivery of the electrode wire with a diameter of 1.2-1.6 mm into the welding or cutting zone (Fig. 94). It consists of a special DC motor M (not visible in the figure), reducing valve 4, feeding unit 2 consisting of two rollers, of a current contact, cartridge 20 for the bare electrode wire and of a container (housing) 1 in which it is mounted. Regulation of the rollers' pressure is accomplished with a screw equipped with a spiral spring.

The feeding mechanism is mounted on base 16 with an insulating lining. Base 16 is rigidly connected with the cover of housing 6 and is held on it. In order that the mechanism would easily fit into the housing, in the preparation of the mechanism for operation or after the routing openings connected e.g. with loading the cartridge with wire, at the base 16, slider 18 is provided with a finish smooth enough to assure sliding.

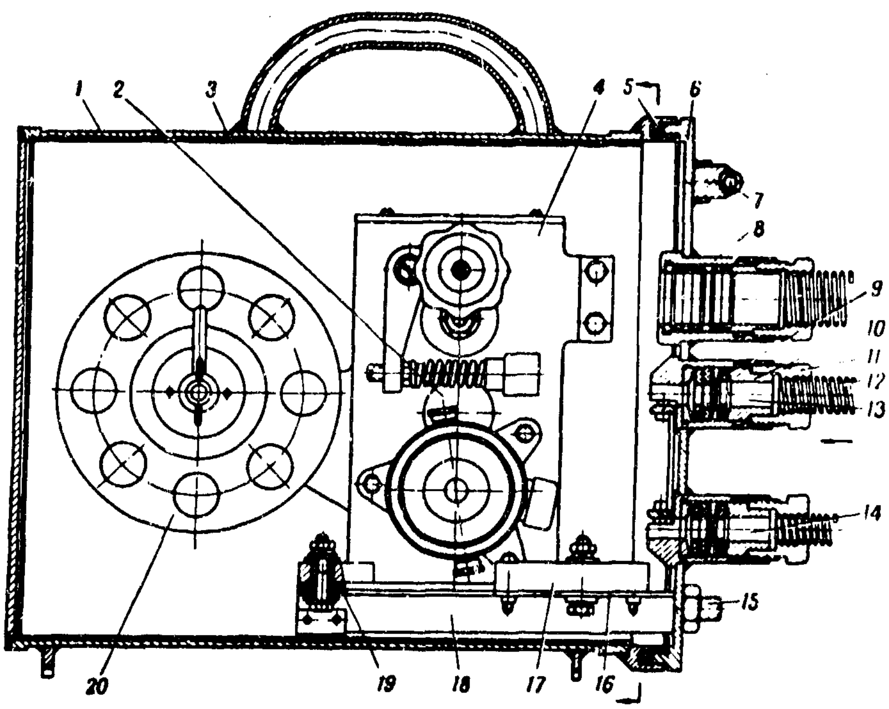


Fig. 94. Mechanism for Supplying the Electrode Wire of the Semiautomatic Machine: 1 - housing (container); 2 - feeding unit; 3 - insulating sheet; 4 - reducing valve; 5 - rubber gasket; 6 - housing cover; 7 - oxygen adapter; 8 - inlet for welding cable; 9 - packing disks; 10 - bushing; 11 - pressure nut; 12 - helix made of stainless steel; 13 - outlet for hose-cable; 14 - inlet for control cable; 15 - coupling bolt; 16 - base; 17 - contact clamp for welding cable; 18 - slide with finishing; 19 - unit for attaching feed mechanism to base; and 20 - cassette (box) for electrode wire.

The delivery of the electrode wire to the zone of welding (of the arc) is achieved by the feed rollers through a guide tube by means of a flexible hose-cable and the current-conducting tip of the head. In the delivery of the electrode wire, the pressing (driven) roller is forced away with the aid of a flywheel. The rate of wire delivery changes smoothly with the aid of a regulator connected from the front panel of the control cabinet, in the limits ranging from 3.5 to 14 m/min. The cover to the bin is fastened with the aid of 5 coupling bolts. The vacuum seal of the bin at the places of the socket and the inlets is provided with gaskets and with the rubber lining 5.

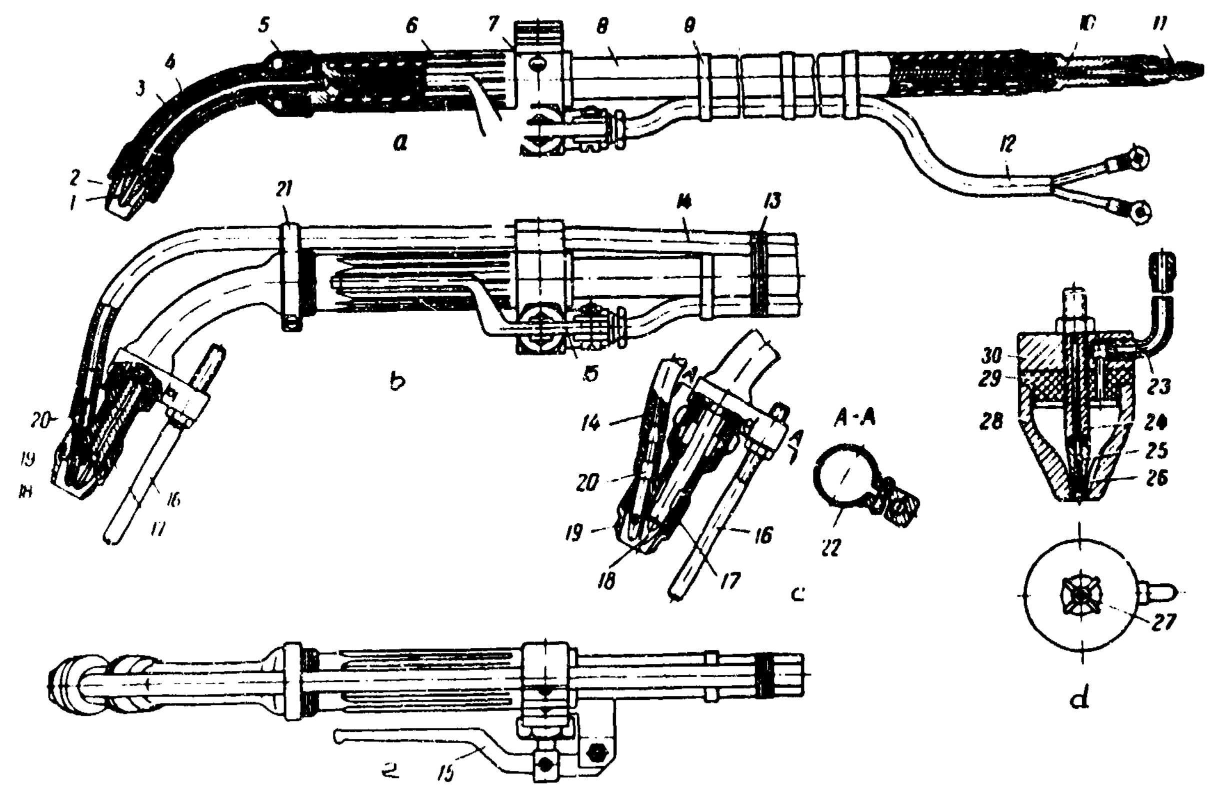


Fig. 95. Head of Semiautomatic Machine for Underwater Welding and Cutting: a - head with welding attachment; b - head with attachment for cutting; c - cutting unit; d - cutting attachment with concentric delivery of oxygen; e - view from top; 1, 18 - current-delivering tips; 2 - nozzle; 3, 4, 23 - pipes; 5, 30, bushings; 6 - lever; 7 - starting unit; 8 - hose-cable; 9 - ring; 10 - spiral; 11 - adapter (nipple); 12 - multistranded lead of control circuit; 13 - lashing; 14 - oxygen hose; 15 - lever; 16 - pin; 17 - removable cutting fitting; 19 - nozzle of cutting attachment; 20 - oxygen nozzle; 21, 22 - clamps; 24, 25 - bronze bushings; 26 - keyway; 27 - X-shaped groove; 28 - bronze frame of fixture; and 29 - polyethylene ring.

The bin's dimensions are 473 X 386 X 330 mm; its weight including the feeding mechanism but without loading the cartridge with wire is 32 kg. The weight of the wire load is about 3 kg or 300-330 m in length with a diameter of 1.2 mm; this supply is enough for 2 hours of work. The wire's feed rate does not depend on the voltage in the arc.

The bin's unsinkability is provided by the carbon dioxide (or air) pumped in under pressure, corresponding to the submergence depth and somewhat exceeding it.

For the fine adjustment of the pressure and its maintenance within the required limits, use is made of a valve mounted in the bin's lid.

The hose-cable 8 (fig. 95) serves for delivering the carbon dioxide, wire and electricity to the head. It passes through the head's handle and forms an integral unit with it.

The base of the hose-cable is formed by a helix for the delivery of the electrode wire which is made of stainless wire, brand 1KH18N9 complying with GOST 5632-61. For better assurance of the passage of the electrode wire within the helix, the latter is made from wire having a rectangular section. A steel braiding is placed on it, and then for insulation, a rubber jacket (tubing) is used, on top of which the welding line is placed; this line is divided into strands which are evenly distributed over the circumference (perimeter) of the helix. The durite hose is then installed. Both the helix and the current-conducting strands are attached to the front bushing of the head.

The welding current is supplied to the head through a block fastened to the feeding mechanism. The hose-cable is 3 m long. It is made flexible in order not to create an impediment to the diver during his manipulation of the head (welding torch). /146

The welding head (torch) has removable attachments, i.e. for welding (Fig. 95a) and for cutting (Fig. 95b, c). In the cutting attachment at the optimal angle $\alpha = 18^{\circ}$, the delivery of oxygen and of the electrode wire is combined.

The head is designed for welding with electrode wire of two diameters (1.2 and 1.6 mm) with currents up to 300 amps. Therefore there are two current-conducting tips 1 in it. The current line of supply, achieved from the copper tube 3 bent at an angle of $60^{\circ}$ with a steel guide tube pressed into it, is inserted into the copper tube 4 insulated from tube 3. Outer tube 4 is covered with a rubber casing.

The tubes are connected with the bushing in handle 6 made of corrugated rubber, on which there is also fastened the starting unit 7--a pushbutton type contact for the remote control of feeding the wire and the oxygen. Oxygen is fed only during cutting. The starting unit is provided with lever 15 located under the diver's fingers. The lever presses on the button, closing the control circuit, activating the wire feed mechanism and closing the welding contactor, while during cutting, it closes the oxygen valve (KK). The diver thus has the possibility of controlling the starting of the semiautomatic machine and the welding (cutting) process without sending a special command to the surface, i.e. he accomplishes the control directly from under water, without changing the position of his hands.

In the performance of the oxy-electric cutting, in addition to the replacement of the fitting (attachment), through clamps

21 on handle 6 there is drawn the oxygen hose 14 and it connects with oxygen nozzle 20.

To maintain the head at a constant distance from the object which is being cut, the support pin 16 is provided.

We have recently developed a cutting attachment with a concentric arrangement of the electrode and a jet of cutting oxygen (Fig. 95d). The attachment provides the possibility of /147 cutting metal with a thickness up to 80-100 mm during continuous operation of the semiautomatic device.

However, it is worth pointing out that in the performance of the tasks with this attachment, there is a significant increase in oxygen consumption. Therefore the work with this fitting during the cutting of slight thicknesses is not feasible. At the same time, during its passage through the nozzle the oxygen jet cools it and thereby raises its strength.

Moreover, the presence of the polyethylene ring 29 permits us to place the fitting, during cutting, by its end against the object similarly to the underwater BUPR gasoline cutter, for which the X-shaped groove is provided in the nozzle. Such a setup of the attachment permits us to do without pin 16.

The kit of the semiautomatic device includes instruments, a clamp for fastening the reverse welding cable to the object which is being welded or cut, plus a supply of spare parts, specifically the replacement outer nozzles 19, and also a rotameter for measuring the gas consumption during the operation (not shown in the diagram). The outer nozzles are made of textolite and therefore quickly burn out.

Operation of the Semiautomatic Machine for Underwater Welding and Cutting. The assembly of the unit (of the semiautomatic device) and the attachment (connection) of the cables and hoses are conducted in accordance with the assembly procedure

(Fig. 92). Control cabinet 2 is connected to the network by leads with a section of 1.5 $mm^2$. Since the welding with thin wire is conducted on reverse polarity, the reverse lead (cable) with a section of 50 $mm^2$ is connected by one end to the minus terminal of the welding generator and by the other end directly to the object, if possible close to the welding site.

The second direct lead (cable) with a section of 50 $mm^2$ is connected by one end to the plus terminal of the welding generator, while its second end is connected to the terminal of contactor 10 (Fig. 93) in control cabinet 2 (Fig. 92). To the second terminal of contactor 10 (Fig. 93) there is connected the welding cable of the same section, from the feed mechanism (Fig. 92). The welding head 16 is connected along with hose-cable 14 to the wire feed mechanism through the appropriate inlet (lead-in).

For supplying the semiautomatic machine with carbon dioxide, on the carbon dioxide tank 8 to eliminate the freezing of the reducing valve during the removal of gas, there is installed the reducing valve 9 equipped with the electric heating unit 3. Simultaneously, a gas consumption meter (rotameter) is installed. If the feeding of the welding current is accomplished from a special power source, the gas heater can be connected with it by a lead having a section of 1.5 $mm^2$; however, if the operations are conducted from another welding installation, power is furnished to the heater from a 48 volt-network.

During the semiautomatic underwater cutting, an oxygen hose mounted (fastened) on the head is connected with adapter 7 on the cover of bin (container) 6 (Fig. 94), while the latter is connected by the oxygen hose directly with the oxygen valve, KK 12 is connected by a hose with the oxygen reducing valve installed on the collector or ramp of the oxygen tanks.

The semiautomatic machine is checked for operation at depths up to 60 m both in fresh and in saline water.

In the utilization of the semiautomatic machine, it is necessary to verify that in the connection of the welding head with a flexible hose to the feed mechanism, the tip of hose-cable 14 is placed exactly opposite the groove of the driving roller and is separated from it by a distance of not more than 1-2 mm.

The filling of the electrode wire in the hose-cable is conducted with turned-out tip (adapter, nozzle); moreover, it is necessary to make certain that the end (face) of the wire has been carefully rolled (rounded), and that the wire itself has been carefully cleaned of dirt, grease and rust.

The channel of the helix for the supplying of the electrode wire should be periodically cleaned of accumulated dirt and rust. For this purpose, the hose-cable is placed on a horizontally extended wire with a diameter of 1.6 mm and a length of 5-6 mm. The hose-cable is then moved repeatedly along the extended wire, while at the same time one performs rotating motions; in this manner, the hose cable moves in a spiral. After the mechanical cleaning conducted in this way, the hose-cable is blown clean with compressed air under a pressure of 3-6 atm.

If the hose-cable is badly soiled and the wire feeds poorly, for 10-15 minutes we pour 25 g of aviation gasoline or alcohol into it; the dirty gasoline (alcohol) is then removed and the /149
hose-cable is carefully blown clean with compressed air.

In turning the cutting attachment in the current-conducting tube, it is necessary to see that the tip of the cutting attachment has been set in the plane of the head, i.e. that the wire and the tip were in one plane (the cutting plane). If it turns out that at this time, the tip is not turned as far as it will go, it is necessary to install one or several washers in order that the tip would be tightly pressed.

It is necessary to monitor the normal pressure of the feed device roller in the delivery mechanism. In case of insufficient pressure of the spring, the feeding roller can slip and the feeding of the wire will be irregular. In case of wear to the roller, it should be replaced. To assure the normal functioning of the semiautomatic machine, one should also:

--check periodically (at least once per month) the oil level in the reduction gear of the wire feeding mechanism (it should be filled to the 2/3 level); for lubricating the reduction gear, we use 1-13 lubricant (grease) in compliance with GOST 1631-61;

--periodically check the condition of the contacts on the magnetic starter (contactor) and clean them; one should also tighten up the threaded connections and other electric contacts; and

--inspect the conditions of the commutators and brushes in the generators; any carbon deposits should be cleaned off; if the brushes have become chipped or worn, they should be replaced.

In the assembly of the system, prior to the diver's descent it is also necessary to check the proper condition of all units in the installation (semiautomatic device), particularly the condition of the nozzle and tip of the welding head; when necessary they should be replaced (if they have become badly burned or spattered with metal).

Before lowering the semiautomatic device into the water, the carbon dioxide gas supply is opened; based on the rotameter, we adjust the gas consumption in such a way that during the entire sojourn under water, the container would be filled with gas and its emergence from the tip of the welding torch would not be interrupted.

During welding in the overhead position, when the work is /150
done without delivery of carbon dioxide to the arc, a stopper is activated, and to avoid the sinking of the container, hoses and head, the carbon dioxide is fed only to provide support. In this case, the diver should monitor the uninterrupted flow of gas from

the tip of the head (welding torch) very carefully.

To reduce the no-load voltage of the welding generator and also to curtail the expenditure of gases and for work convenience, the length of the cables and hoses is selected according to the submergence depth (the corresponding excess lengths are disconnected).

Prior to the dive, we check the airtightness of all the submerging units to the semiautomatic device and the hose connections with the aid of carbon dioxide gas under 0.5 atm pressure.

The container with the feed mechanism is lowered only on a special cable, rigged by the frame handle; lowering the equipment by the welding cable is forbidden.

After the completion of the operations, especially in winter, the moisture (condensation) is removed from the hoses; for this purpose, all the hose connections are uncoupled and the blowing out of the hoses is accomplished. The tasks associated with the repair of the parts and units of the semiautomatic device must not be conducted while voltage is turned on.

If the semiautomatic machine has not been in use for a long time, it is coated with UNZ gun grease complying with GOST 3005-51. The protective coating is checked at least once every 6 months.

It is easy for the diver-welders to master the work involved with the semiautomatic device, since the maintenance of the arc and the control of the process have become greatly facilitated.

A disadvantage in the design of the semiautomatic machine is the rapid breakdown of the nozzle to the welding head and to the cutting attachment owing to the appreciable concentration of heat.

### Section 38. Supplies, Tools and Appliances for Underwater Semiautomatic Welding and Cutting

In the semiautomatic underwater welding, we use the conventional auxiliary tools at the disposal of a welder: wire brushes, chisel, hammer and so forth. We apply the welding wire Sv-08G2S /151 (GOST 2246-60) with intensified content of manganese and silicon (See Appendix 7). For the cutting, use can be made of any low-carbon wire, e.g. the Sv-08 welding wire.

During the welding with supply of carbon dioxide to the arc, we utilize rarefied carbon dioxide (GOST 8050-64). During the evaporation of the rarefied carbon dioxide, intensive cooling occurs; this can lead to the freezing of the reducing valve, therefore on it or in front of it, we install a special electric heating unit, included in the kit of the semiautomatic machine. During welding with an unshielded arc, for sealing the head and the semiautomatic device's units which are submerged in the water, carbon dioxide is utilized. For this purpose, it is supplied under pressure to the system, compensating the pressure of the water column during submergence.

For back pressure, use can be made of the air (from the ship's compressor) passing through the oil-water separator; however to avoid the random entrance of air into the molten-metal pool and the possible nitration of the joint, it is better to employ carbon dioxide.

During cutting, just as for similar operations at the surface, technical oxygen (GOST-5583-58) is used. For measuring the expenditure of the gases (oxygen or carbon dioxide), a type RS-5 rotameter (gas consumption meter) is installed.

### Section 39. Power Sources for Underwater Semiautomatic Welding and Cutting

As experience has shown, for powering the arc during semiautomatic welding under water, the PAS-400-VI welding installation can be utilized only with the switching to series-winding for matched connection and to shunt winding for independent power supply and with attachment of the PM-1 fitting.

Industry is mastering the production of special power sources supporting the semiautomatic and manual welding under water.

The magnetic PM-1 fitting provides the formation, at the welding generator, of rigid external characteristics with intensified no-load voltage. The PM-1 unit is a small device weighing 12 kg. It consists /152
of a magnetic amplifier (МУ), a voltage stabilizer (CH) and a selenium rectifier (BC). Its functioning is based on a reduction of the inductive resistance in the AC circuit during the magnetization of the iron by a constant magnetic field.

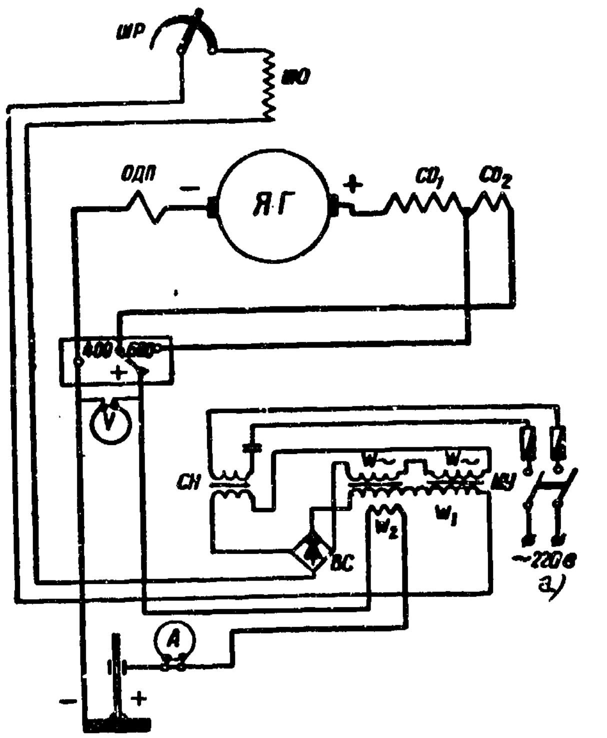



Fig. 96. Main Electrical Circuit for Connecting the СГП - 3-VI Generator (of the Р -400-VI subassembly) with the PM-1 Unit; ЯГ = generator armature; $CO_1$ = series winding (4 coils); $CO_2$ (series winding) (2 coils); ОДП = winding of supplemental poles; ШР - shunt regulator; ШО = shunt winding; МУ = magnetic amplifier; CH = voltage stabilizer; BC = selenium rectifier; $W_{\sim}$ = AC winding of fitting; $W_1$ = feedback winding based on amplifier's

load current; $W_2$ = feedback winding based on welding current; V = voltmeter; and A = ammeter.
Key: a) About 220 volts.

The main electrical circuit for connecting the СГП -3-VI generator (PAS-400-VI subassembly) with the PM-1 unit is shown /153
in Fig. 96.

For working with the PM-1 fitting during the underwater semi-automatic welding, an additional AC power source of 220 v is required with a force of not less than 0.5 kw. This is provided either from the power system at the ship repair docking facilities or from an onboard AC power source.

CHAPTER 8

# DRILLING, CUTTING AND OTHER MINOR OPERATIONS PERFORMED UNDER WATER

## Section 40. Drilling and Cutting of Holes Under Water

In underwater conditions in the performance of the hull tasks, it is necessary to drill new holes, to redrill old ones, to countersink and to ream the holes, and to drill out rivets.

Drilling holes under water is one of the laborious operations; a solid support is required. If the work is done from a scaffold, drilling is performed with the utilization of a side lever.

In this case, to the hull sheathing we weld a pin with an eyebolt, on which a lever plate is hung. With its aid, we press on the cross piece of the drilling machine.

During the work at the side, the pressure is exerted from the upper deck at the command of the diver, whose role consists of holding the drill in the required position and observing the progress of the drilling (Fig. 97). At a great depth in case of working on a sunken object, the drilling operation is performed by two divers; one of them holds and guides the drill while the other presses on the lever.

If the work is done from the sea floor and the ship's sheathing thickness is more than 8 mm, during the drilling use is made of a supporting bracket welded to the side (Fig. 98). The drilling is done with pneumatic drills of the piston or rotor type, or with electric drills. Before the drilling, a layout is made and the /155
centers of the future holes are marked with a prick-punch.

The drill is gripped in the chuck and the drill is lowered on a line to the diver. The diver places the drill point on the marked center, perpendicularly to the drilling plane, and then the machine is started. Just as at the surface during the drilling of large holes, a small hole of 6-8 mm is first drilled, and then the hole is drilled to size.

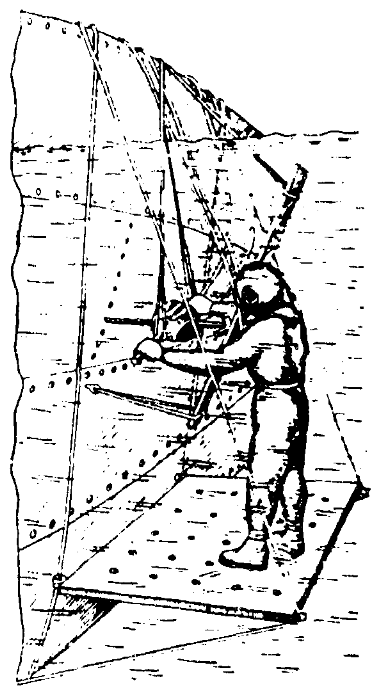


Fig. 97. Drilling Holes in a Ship Hull with Pneumatic Drill, Using a Plate Lever Rig.

If the drill jams in the metal, one should first cut off the air supply and then extract the drill bit. The drill should be withdrawn in such a way as to retain its perpendicular position relative to the drilling surface.

Before the withdrawal of the drill from the metal layer, the drill's rpm should be decreased, so that the machine would not be jerked out of the diver's hands from an abrupt jolt. During drilling, defects develop: the drift of the drill to one side (skewing), the formation of "figure eights" (noncoincidence of the holes in the adjoining sheets or elements of framing), displacement of a hole owing to inaccurate drilling or marking out, etc. In these instances, the holes are welded over and then new ones are drilled. If the damage is slight, it is eliminated by reaming or by additional drilling of the holes. The operations on reaming and countersinking /156 are also conducted with hand-type drills. Moreover, the drills are utilized for cleaning and chipping the welded seams of the ship's hull.

For this purpose we insert a wire brush or a grinding wheel into the drill chuck.

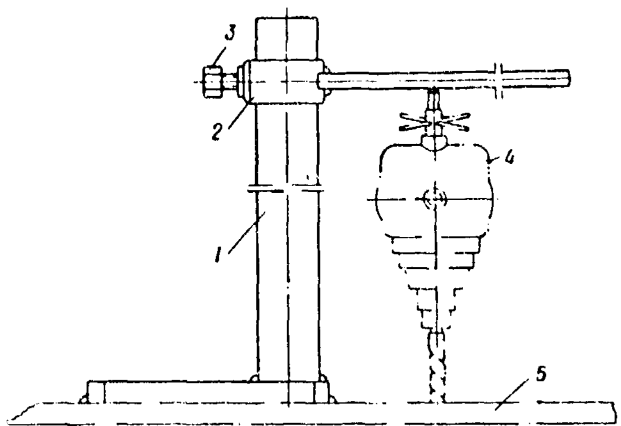



Fig. 98. Supporting Bracket for Drilling Holes Under Water: 1 - support; 2 - slider; 3 - stay bolt; 4 - drill; and 5 - outer sheathing of ship.

During the repair of the hull, it is sometimes necessary to drill out the old rivets. Basically this job does not vary in any way from ordinary drilling but it does demand greater accuracy and attentiveness on the part of the operator.

The cutting of holes is a task typically performed during ship hoisting and is accomplished by the flame method (gasoline-oxygen, oxy-electric or electric-arc cutting). These are usually large holes, e.g. holes for the mounting of coamings, sluice shafts and so forth.

Care is exerted in the performance of these tasks, since usually data are not available on the material located behind the surface which is being cut. Therefore during the application of the flame cutting, a hole is drilled with a pneumatic tool or electric instrument. If there are combustible gases or liquid (which should be established by analyzing the sample), it is necessary to pump them out and to fill the compartment with water. /157

The cutting of the holes begins from the "prick mark", and then the cutting is performed as was described above (see Chapt. 6).

Section 41. Underwater Cutting of Metal

In underwater ship repair, the cutting of metal is utilized mainly in the trimming of the edges of sheets to be welded and during their cleaning, the dismemberment of sheets of slight extend when it is not possible to utilize flame cutting, during the removal of rivet heads, the re-cutting of cables, chains and so forth. Metal cutting differs according to position in space, angle of edge being cut and in smoothness of finishing.

According to orientation in space, cutting is usually from above (in the downhand position), from the side (in a vertical position) and from underneath (in overhead position). In underwater ship repair, we use chiefly the cutting from the side and from below, i.e. in the vertical and overhead positions.

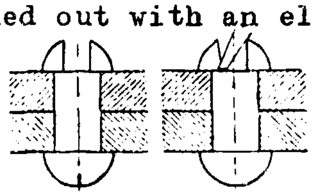
According to the angle of the edge which is being cut, we differentiate cutting with removal of chamfers at an angle of 30-60$^{\circ}$, and during the cleaning of edges, we use the so-called standard cutting at an angle of 90$^{\circ}$. In respect to smoothness of finishing, we have the rough and fine cutting. Rough cutting is the trimming away of the irregularities on the edge, the removal of bulges in the welded joint (e.g. in case of butt-welding with plates), etc. while fine cutting is the cutting to size, according to a reference line.

The cutting tasks are performed with cutting hammers or, in the event of small scale operations and sheets of slight thickness, the tasks are done with cutting-chalking guns. The diver holds the pneumatic hammer with both hands: with the left hand, he guides the chisel edge along a line marked in advance (a reference line or line marked with chalk which has been boiled in grease), while with the right hand, he presses on the hammer, aided by the hull.

The cutting is performed from one of the ends of the edge, along it from right to left. If the surface is dirty or has become fouled by barnacles and algae, a sector of the sheet edge is first cleaned off. The thickness of the metal chips is selected in relation to the sheet's thickness and the actual conditions of the work being performed.

If the metal has a considerable thickness and the removal of one shaving is insufficient, the process is repeated. The trimmed edges should not show scratches or burrs. When cutting a hole in the middle of a sheet, a slot is first cut with a groove chisel, and the groove is then cut deeper with a standard chisel until the opening has been completely cut. /158

Cutting off the rivet heads needing replacement is done in the following sequence: first a groove is cut across the diameter of the head (Fig. 99a), then half the head is cut away (Fig. 99b); the rivet shank is knocked out with a punch or is drilled out. Rivets are often burned out with an electric arc.



a б

Fig. 99. Cutting Off a Rivet Head: a - groove has been cut; and b - trimming off the remnants of the rivet head.

During the work with a cutting hammer, definite rules are observed. Before releasing the air to the cutting hammer, the chisel is placed tightly against the edge which is being cut off. If this is not done, during the delivery of air, the strikers of the gun could break the support ring or the gun might jump out of the diver's hands.

In preparing the sheets for welding, the edges should be treated with particular care, since inaccuracy in the amount of clearance can cause damage. The correctness of the opening angles and the amount of the clearances are checked with templates. The following defects can exist during cutting: violation of dimensions, burns, and curvature of the edges.

## Section 42. Cutting and Trimming of a Cable and Anchor Chains Under Water

The cutting of a steel cable is done with a chisel and anvil. We do not recommend cutting a cable which is under tension. If it is impossible to slacken the tension on the cable, in order that the cable ends at the moment of completion of the cut would not "jump" and injure the diver, prior to the cutting the place of cutting should be served with a rope from two sides and tied with a span to the ship's side.

The cable can be cut through with the aid of hand cutters. For this, we use a lip to separate the strands and we cut through them /159
with special cutters (Fig. 100) or with conventional metal-cutting shears.

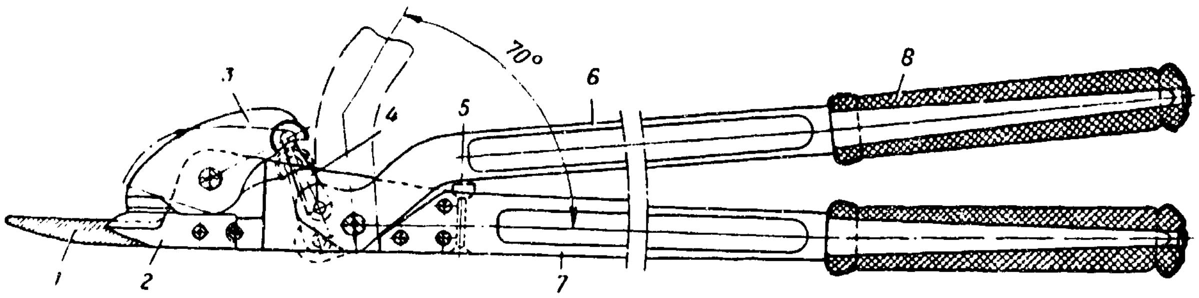



Fig. 100. Shears for Cutting Steel Cable: 1 - steel lip; 2 - stationary cutter; 3 - mobile cutter; 4 - pivot; 5 - stop block; 6 - upper lever; 7 - lower lever; and 8 - handles.

When underwater conditions are involved, steel cables with a diameter up to 65 mm both freely suspended and also wound on the propeller shaft can be cut with the assistance of a circular tool powered by an electric drive. The cable can be cut through in 15-20 minutes. If the cable is tangled on the propeller and is jammed between the propeller's hub and mortar, which is a fairly common occurrence, and provided that conditions permit, the propeller shaft is disconnected and is moved slightly into the stern. If the wound cable is tangled and wedges and can not be unwound, it is cut through blow by blow with mechanical means, or with flame cutting. Rope cables are cut through with a diver's knife.

The flame cutting of a cable wound onto the propeller is achieved with an electric-arc or electrode method. The cable is cut gradually, starting from the upper turn. During the cutting of the last turn, caution must be exercised in order not to damage the propeller shaft or the propeller hub. If the cable is jammed in the space between the hub and the mortar, it is necessary to hold the electrode at a tangent to the cable's circumference. /160

It is recommended that the final turn of the cable be cut off with the electric-arc method by successive ignition of the arc. In this case, at the point of the arc's excitation, the steel strands of the cable quickly burn, and we exclude the chance of damaging the propeller hub, mortar or the propeller shaft. If possible, we place a metal or wooden insert under the final turn of the cable. The current force is chosen according to the cable diameter, but lower by 15-20% than in the cutting of a solid section of the same thickness.

When it is necessary to free a ship from the bonds retaining it but there is no opportunity to haul in the anchor, the cutting of the anchor chain is accomplished. Cutting the chains is performed chiefly by the flame method. The conditions are selected to be the same as in the cutting of round sections. The cutting of the chain links is achieved along with the cutting of the tie-pieces. At this time, the diver's position should be such that the cut-off falling ends of the anchor chain would not catch the diver.

### Section 43. Chasing (Calking) of Riveted and Welded Joints Under Water

In underwater ship repair, the calking with pneumatic cutting-calking guns is used for tightening the riveted and in part the welded joints. The method of chasing the edges depends on the design of the joint (butt or lap, scraped or unscraped edges, etc.).

If the sheathing sheets have been machined at a right angle, or are not machined at all, it is necessary to remove the bevelling prior to the calking. During the chasing of unmachined edges, the calking chisel is held at an angle of 35-40°, with the acute angle upward (Fig. 101a). The edge of the sheet is swaged to a height about equal to 2/3 of its thickness. The groove (Fig. 101b) which had formed in the edge is cut out from above with a chisel and a bevel (chamfer) is developed. Then using a curved calking tool, the edges are closed (Fig. 101c), and it lies closely against the adjacent sheet. For a tighter fit of the sheets with one another, a repeated closing of the edge is conducted with a calking tool having a narrower face (striker).

During the calking of the scraped edges, we conduct the same operations, but the initial groove is made with a calking /161
tool having a rounded striker (Fig. 102a). It should be taken

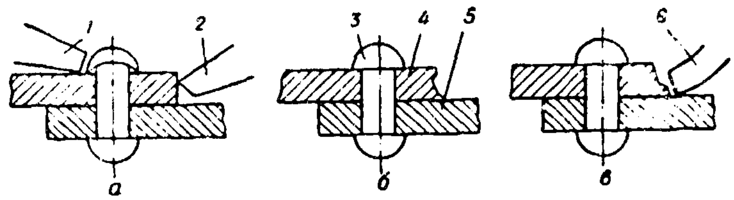



Fig. 101. Chasing of Unscraped Edges. Tightening a defective rivet with a half-round (standard) head: 1 - calking tool for swageing the rivets; 2 - calking tool with acute angle for chasing the edges; 3 - rivet; 4 - edge of sheet with groove after chasing with calking tool 2; 5 - edge of sheathing sheet; and 6 - curved calking tool for closing the sheets' edges.

into account that during intensive and prolonged calking, the sheet's edge starts to bend, a gap forms between the edge and the rivet, and instead of closing the joint and stopping the leakage of the seam, the filtration could increase, especially when we are working in underwater conditions where the ship hull is subjected to the hydrostatic pressure of the outside water (Fig. 102b). During the chasing of the edges, in order to avoid damage to the lower sheet (Fig. 102c), one should never position the calking tool with the sharp edge downward.

With the aid of calking, we reinforce the weakened heads for the rivets. For this purpose, the calking tool with concave striker is positioned at a certain angle and is moved around the entire circumference of the head, during which time the tool /162
should be held perpendicularly to the surface of the rivet head

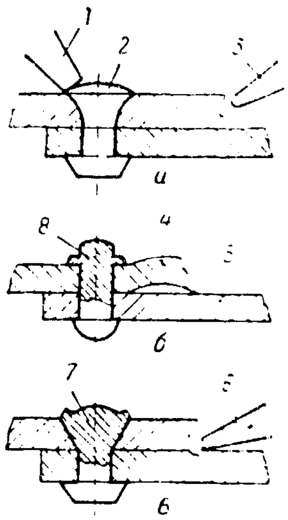


Fig. 102. Defects Developing During the Chasing of the Edges. Consolidation (closing) of defective rivets: 1 - calking tool for swageing the rivets; 2 - faulty rivet with sunken head; 3 - calking tool equipped with rounded striker for chasing the unscraped edges; 4 - damage caused by excessive calking of edge -- the edge has been bent and formed a gap; 5 - sheathing sheet; 6 - improper position of calking tool -- acute angle downward, as a result, an undercutting of the edge to the sheathing's sheet; and 7, 8 - closing the rivets with intensive upsetting (swageing).

(Fig. 101a). After this, with a curved calking tool (Fig. 101c), we conduct the closing of the edges by blows from a calking gun. If water leakage is detected in a riveted joint, we first accomplish the tightening of the heads of individual rivets and then we chase the edges of the sheet.

If a rivet has become greatly weakened, it is tightened by intensive upsetting of the head from above (Fig. 102, b,c), and by a subsequent calking of the edges or welding around the heads. With a thickness of sheets less than 5 mm, one can never tighten the riveted joints by calking, since the sheets would bulge out. In this eventuality, the leakage is eliminated by welding the edges of the sheets and by welding around the rivet heads.

Section 44. Tools for Underwater Hull Operations

For the accomplishment of the ship assembly and hull operations under water, use is made of the identical tools as during the activities at the surface. Use is made of the pneumatic drills, type SM-22E, SM-32E, RS-22, RS,32, SPU and others, as well as of electric drills, the RB-54, RB-58E, RB-63 and ERK-9 pneumatic cutting- calking guns, type RK hammers, pneumatic wrenches, circular cutters, metal cutting shears, and so forth.

An electrically-powered tool has an advantage over the air-powered tool in that its functioning does not depend on the submergence depth, whereas the pneumatic tool can operate only within the limits of the depths established by the strength of the hoses supplying the compressed air.

Moreover, the electric tool causes almost no bubbling (emission of used air into the water), which would interfere greatly with the work, and in combatting it, one must use diversion hoses equipped with a float. The maintenance (servicing) of the electric tools is simpler.

The general-purpose pneumatic tool has been described in detail in the literature, therefore we will present here a brief description of the specialized tool suitable for use in underwater conditions.

The underwater pneumatic tool has in its exhaust nozzle a special fitting to which there is connected the air-diverting hose with a length of 1.5 - 2 m and attached to a cork-type or other /163
float, reinforced padding of gaskets and general sealing.

Experience has indicated that the sealing of the general purpose pneumatic machines is quite adequate for their utilization under the conditions of underwater ship repair provided that the additional requirements listed above are fulfilled.

During work at a great depth, one applies only the special (underwater) pneumatic tool, capable of withstanding a great hydrostatic pressure. In this case, we recommend that the air outlet hose be extended to the surface in order to avoid power losses. The following specialized devices are utilized for the underwater operations.

The SPU Pneumatic Angular Drilling Machines (Fig. 103) are used for drilling holes up to 23 mm in diameter in corners and other difficultlyaccessible locations, and also for countersinking, reaming of holes and the chasing of threads. The pneumatic angular drilling machine consists of four main units, i.e. of a drilling head, a rotor motor equipped with a centrifugal regulator, a planetary reducing gear and a starting lever.

In the drilling head, there is mounted the shaft 39; in its tapered recess, there are inserted the spare working tools, i.e., the drills, countersink reamers, etc. The rotation of shaft 39 is accomplished from the rotary motor through the planetary single-stage reducing gear; the latter's central gear 33 is connected by a threading to rotor 31 and to the pair of bevel gears 4 and 40.

Rotor 31 of the motor has six slots with textolite blades 12 moving freely in them, and is arranged eccentrically in relation to stator 11. Holes are drilled in the walls of stator 11 for the delivery of compressed air to blades 12 and grooves have been milled out for the release of the spent air from the machine.

For purposes of reducing the wear on blades 12 and also for raising the efficiency of the pneumatic motor, automatic lubrication is provided in it. The spindle oil poured into the specially provided chamber 27 in the head of housing 13 is sprayed by a compressed air jet into the working cavity of stator 11.

The rotor turns in two ball bearings mounted in the covers 28 and 32 of the motor. The motor is equipped with a centrifugal ball- /165
type regulating device; and its aid, we accomplish automatically the control of the number of revolutions of rotor 31. The centrifugal regulator is set for 4500 rpm at no-load operation of the machine. Adjustment is achieved with the aid of a spring and the special nut 30.

At an increase in the rpm of the rotary motor, the axial component of centrifugal force of the balls acting on cap 26 will exceed the tension exerted by spring 16 and will move cap 26 along with slide valve 14 in the slide valve bushing 15; as a result, there will be a reduction in the flow passage area of the latter's ports signifying the admission of compressed air into the motor. The number of motor rpm will diminish and under the effect of spring 16, cap 26 will return to its original position, while the flow passage cross sectional area of the ports in slide valve bushing 15 will be restored.

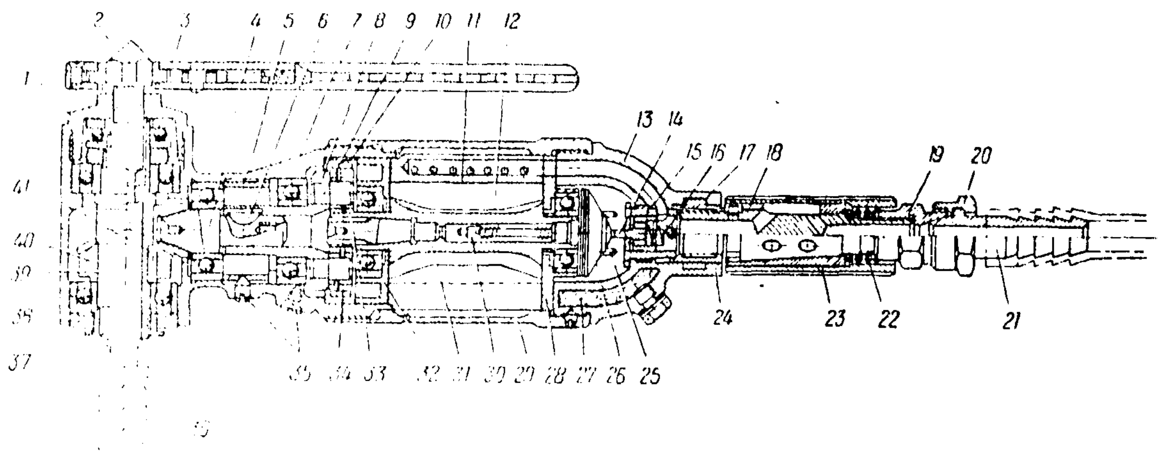



Fig. 103. The SPU-23 Pneumatic Angular Drill: 1 - cover of head; 2 - tool post; 3 - ratchet wrench; 4 - bevel gear; 5 - bushing; 6 - key; 7 - frame head; 8 - guide; 9 - pin; 10 - crown gear; 11 - stator; 12 - rotor blade; 13 - housing head; 14 - slide valve; 15 - bushing of slide valve; 16 - spring; 17 - bushing; 18 - conical bushing; 19 - connecting piece; 20 - coupling nut; 21 - nipple (adapter); 22 - spiral spring; 23 - clutch; 24 - bypass pin (stud); 25 - pin; 26 - cap; 27 - lubrication chamber filled with wool wadding soaked with spindle oil; 28 - rear motor cover; 29 - housing sleeve; 30 - special nut with spring; 31 - rotor; 32 - front motor cover; 33 - central gear; 34 - satellite (intermediate) gear; 35 - screws; 36 - drill; 37 - nut; 38 - ring; 39 - shaft; 40 - bevel gear; and 41 - spline (key).

The machine is started up with a starting lever, i.e. by turning clutch 23 for 1/4 - 1/2 of a revolution. At this time, the air outlet channels of bypass pin 24 line up with the groove in conical bushing 18 (as is indicated in Fig. 103) and the air from the hose passes through the lever (handle). Spring 22 presses bushing 18 against the cone of bypass pin 24 and thereby holds it in a working (matched) position. The machine is stopped by a reverse twist of the clutch (coupling).

The compressed air flows from the starting lever through the ports in slide valve bushing 15 and the curved channel of housing head 13 to stator 11. From there, through two longitudinal channels and a series of obliquely drilled holes in stator 11, the air enters the working chamber of the motor (of the stator) and, exerting pressure on blades 12, it forces rotor 31 to rotate.

For feeding the machine during the drilling and removal of the working tool from the recess of shaft 39, there is the tool post 2, which can be turned with the ratchet wrench 3.

In working with the machine, it is necessary to monitor the proper condition of the mechanism, to perform timely lubrication and to keep it clean, to prevent the entrance of moisture, since when exposed to water, the blades of the rotary motor could expand and become jammed. In installing the drill, it is necessary to position /166 it properly. During turning, a badly installed tool could jump out of the chuck and injure the operator. Should any jamming of the tool occur, it should be stopped and brought to the surface; we recommend disassembling it only after the pressure has been shut off. The technical specifications are listed in App. 22.

**The pneumatic wrenches** (our industry is producing several standard designs) are utilized for turning bolts and nuts with a diameter up to 85 mm. They have a handy pistol design, small dimensions and low weight (Fig. 104). The front of the wrench serves as a holder for the cam-type impact mechanism, 6. The driven (slave) coupling 3 extending to the outside terminates in a square shank, on which one can use the end wrenches, 1. The wrenches are held in the shank by retainer 19 fitted with spring 2. The housing (cylinder) of impact mechanism 6 has cams on the end, connecting with the driven coupling, 3.

The connection of rotary motor 10 with the percussion (impact) mechanism 6 is achieved via the planetary reducing gear, 8. The rotary motor 10 has a reverse gear and can alter its direction of rotation. For this purpose, switch 9 is installed at the rear part of the wrench's frame.

The turning of nuts or bolt heads is achieved by the transfer of torque from the motor to wrench 1.

However, when the nut or bolt has reached its tightest point, a delay occurs which is accomplished in the following manner.

At the moment of the nut's (bolt's) pressure against the object, the driven coupling 3 is braked or stopped. The cylinder to the percussion mechanism 6, engaged with coupling 3, also stops simultaneously. Under the effect of revolving shank 18, the cylinder of percussion mechanism 6 receives an axial displacement, in which there occurs a compression of the spring contained in it, and the disengagement of the end cams from the cams in coupling 3. As soon as the cams become disengaged, under the effect of the compressed spring, the housing of the percussion mechanism 6 strikes against the cams of driven coupling 3, and hence also against the head of the bolt or nut which is being tightened, since wrench 1 is connected rigidly with it. In this manner, we have several repeated blows directed in a tangent, and the bolt or nut is tightened.

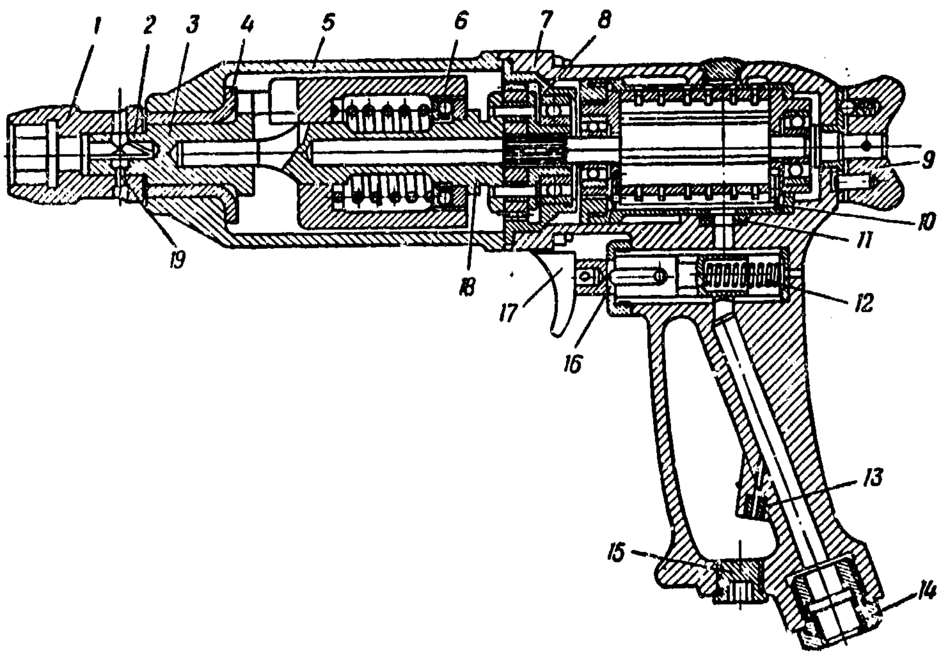



Fig. 104. Pneumatic Wrench: 1 - removal end wrench; 2 - spring;

3 - driven coupling; 4 - bushing; 5 - housing cover; 6 - percussion mechanism; 7 - frame with lever; 8 - planetary reducing gear; 9 - switch; 10 - rotary motor; 11 - rubber lining; 12 - spring; 13 - adapter; 14 - connecting piece; 15 - plug; 16 - trigger; 17 - button; 18 - shank retainer; and 19 - retainer.

The wrench is started by pressing on button 17 of trigger 16. /168
At this time, spring 12 is compressed and the groove provided in trigger 16 lines up with the air outlet drilled in the handle of frame 7. During the operation of the wrench, one should hold the trigger button in pressed position, and during stopping it should be released; under the effect of spring 12, the trigger will return to its original position.

The requirements for care and operation are the same as during the work with the pneumatic drill (see above). The technical specifications are listed in App. 22.

The pneumatic cutting shears are designed for the straight and curved cutting of sheet metal with a thickness up to 3 mm (Fig. 105). With these shears, we can perform the external trimming of a sheet and the finishing of circular holes with a diameter of more than 22 mm. The layout and cutting of the sheets is accomplished according to a pattern (template).

These cutters are comprised of an intake unit, a rotary type of pneumatic motor, a planetary reducing gear, a cutting head with a slide unit 35, die 28, punch 29 and other small components.

The die 28 and punch 29 are fastened in the lower part of the frame of head 2 with the aid of coupling (union) nut 30. With screw 27, the latter is mounted in slide block 35. The cutting head is placed on the projecting part of the frame to reducing gear 23, and meshes with rod 32, seated on the pin of crankshaft 24. In this manner, the turning of rotor 10 through the planetary reducing gear and the crankshaft-rod mechanism is converted to the reciprocal motion of slide block 35.

The starting of the cutters is accomplished with the aid of valve 12, located in the cover to engine frame 14; one simply presses on head 13. At this time, valve 12 is moved to its extreme position, the air outlet openings of valve 12 and the cover of engine housing 14 are lined up and air enters the working cavity (effective chamber) of the rotary motor. Valve 12 is held in its extreme position with the help of retainer 17. To turn the cutters off, the operator presses on the lower head of valve 12, which will assume its former position and stop the supply of air. At this time, retainer 17 enters the slot of valve 12 and holds it in this position. /170

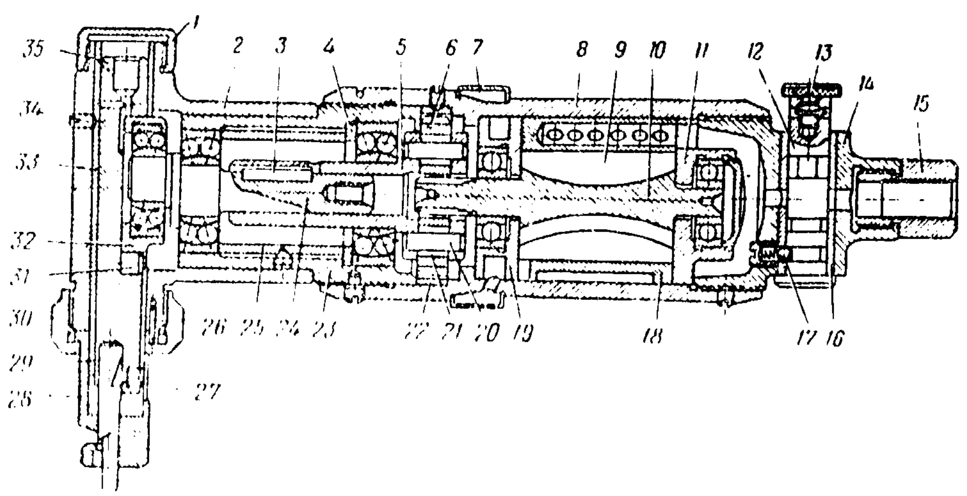



Fig. 105. Pneumatic Cutting Shears (Cutters): 1 - head cover; 2 - head frame; 3 - keyway; 4 - support ring; 5 - guide; 6 - gear; 7 - exhaust ring; 8 - engine mounting; 9 - blade; 10 - rotor; 11 - rear cover of engine; 12 - valve of intake unit; 13 - valve head; 14 - cover of engine housing, where the intake unit is installed; 15 - connecting piece; 16 - engine bushing; 17 - retaining unit; 18 - stator; 19 - front engine cover; 20 - roller; 21 - needles; 22 - crown gear; 23 - reducing gear frame; 24 - crankshaft; 25 - bushing; 26 - pin; 27 - screw; 28 - die (matrix); 29 - punch; 30 - union nut; 31 - roller; 32 - connecting (piston) rod; 33 - bushing; 34 - screw; and 35 - slide block.

Operation of the rotary motor is similar to that of the same motor utilized in the power drill. Cutting a sheet is done from the edge, or (as we have already indicated), the cutting is done through the reaming of holes permitting the thrusting of die 28 of the cutter's head into them.

Die 28 is brought into contact with the sheet's edge and the cutting is performed. At this time, punch 29 is moving up and down. At each stroke of punch 29, a comma-shaped shaving is peeled from the sheet by the punch's blade. By successive motions of the tool, the cutting of the sheet metal is accomplished. With well-organized work habits, one obtains a cut which proves to be both clean and even.

For convenience in working under water with the power cutters, it is necessary to tack-weld a connecting piece to the exhaust ring, and to attach an air-outlet hose to it, with a length of 1.5 m and having a float connected to the end. The technical specifications of the cutters are listed in App. 22.

The electric circular saw (Fig. 106) incorporates an electric motor 9 of submerging type, permitting use in water owing to the sealed special composition of the stator winding; it also includes reducing gear 4 equipped with a pair of bevel gears, and a maximal torque clutch 3 protecting engine 9 from overloads. Also included are the abrasive disk 11 and supports 10. For controlling and moving the saw along a guide line during operation, the frame of electric motor 9 has the handle 5 and lugs 6.

The cutting wheel 11 with a diameter of 175 mm and a thickness of 2-2.5 mm is made of abrasive materials and is reinforced with paper. With the power circular saw, we can cut a cable not only when it is tangled on the propeller or propeller shaft but also when it is hanging freely. We have shown in Fig. 106a the moment of cutting the cable 16, having become wound around propeller shaft 15. For this purpose, posts 10 of the circular cutter are pressed by their base 2 against the cable 16, being cut, with the aid of line 14 encircling shaft 15. Line 14 is fastened to the base of posts 2 with the aid of snap hook 1 and is stretched with hand winch 13. At the base of posts 2, there is a slot through which the abrasive disk (grinding wheel) 11 passes. Cutting the cable

is performed by a successive severing of its individual strands. /171
Moreover, the cut turns out to be wide and thus precludes the binding of the cutter and its premature wearing out.

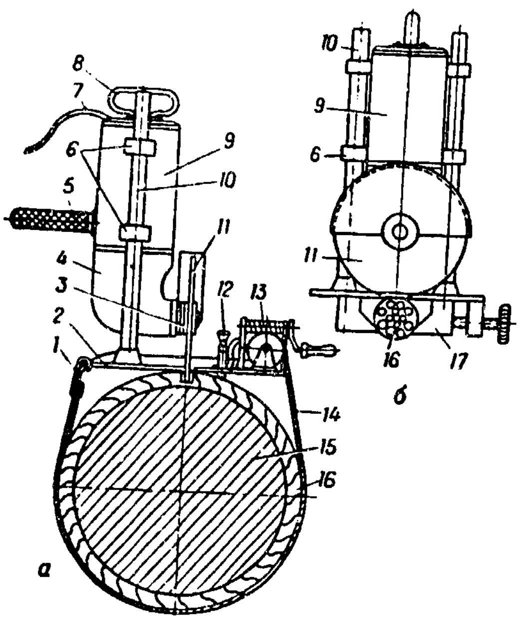



Fig. 106. Cutting a Cable with a Circular Power Saw: a - wound on propeller shaft; b - freely suspended; 1 - snap hook on line; 2 - base of supports; 3 - maximal torque clutch; 4 - reducing gear; 5 - handle; 6 - lugs on motor frame; 7 - current-conducting cable; 8 - handle; 9 - electric motor; 10 - guide posts; 11 - abrasive wheel; 12 - lateral support of post; 13 - hand winch; 14 - line; 15 - propeller shaft; 16 - cable which is being cut; 17 - jaws for gripping cable being cut.

We have depicted in Fig. 106b the cutting of a freely suspended cable. In this instance, cable 16 which is subjected to cutting is pressed against base 2 by jaws 17 provided with special lips. The cable, with a diameter of 35 mm, is cut through in 10-15 min., while it takes only 3 min. to cut through a 1-inch pipe. The power cutter is started by turning handle 5, closing the electric contact.

During the utilization of the circular cutter in underwater conditions, it is necessary to observe all the rules pertaining to /172
to maintenance and safety techniques adopted for the utilization of the electric power tool, including verifying that the cable does not have breaks in its insulation. After use, the tool should

be wiped with a clean dry cloth and the disk should be dried out. When it becomes worn, the disk is replaced by a new one. During the work, it is necessary to insure that the disk is positioned at right angles to the cable which is being cut. Otherwise, it would be possible to have a jamming of the abrasive disk and it could be put out of commission. The disk's technical specifications are presented in App. 23.

The electric power drills for underwater operations (Fig. 107) are designed for drilling holes up to 25 mm in diameter. The presence within the kit of the special post 10 permits the diver to work along without the use of levers. In the machine, we have employed as a diver unit the submerging type electric motor with sealed stator winding. Post 10 is fastened to the ship sheathing 1 with the aid of pins 4, screwed into the sheathing and equipped with lateral supports 5; these are mounted in small, previously tapped holes. Thus, a rigid system is created in the installation of post 10, which provides the development of an axial force during the drilling (axial force up to 300 kg).

During the drilling, crosspiece 8 of the power drill is rested on crossbar 7 of post 10, while drill 14 is inserted into chuck 13. During the work procedure, the diver turns crosspiece 8 and thereby creates an advancing motion of the drill. Starting (turning on the power) of the machine is achieved by twisting the handle, 11.

The requirements with respect to the rules on the safety in use and operation of the drill are the same as for any electric power tool. Its technical specifications are tabulated in App. 23.

The Underwater Hole-Punching Gun (UHPG) is used for punching holes and driving pins into sheets of shipbuilding steel with a thickness ranging from 9 to 25 mm. If the metal's thickness is less than 8-9 mm, a driven-in pin will not hold.

The underwater hole-puncher (Fig. 108) consists of a hollow frame 10, rigged with handle 16 and a hole for mounting the loaded

(assembled barrel) 9 in it. Within frame 10, there are mounted firing pin 14 and the return spring 13, holding barrel 9 in its extreme position. To protect barrel 9 from falling out, in /173
the front part of frame 10, catch 3 with spring 4 has been included. In frame 20, two holes 15 are provided for the outlet of water, while for lowering the gun to the diver, two lugs 1 are incorporated on frame 10.

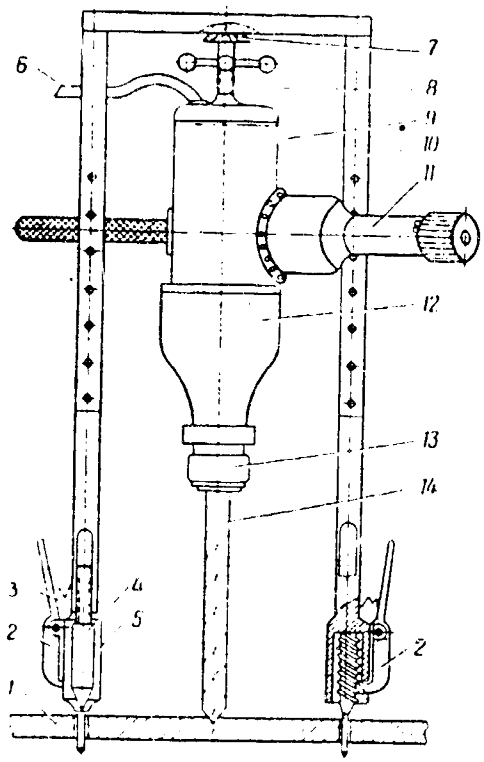



Fig 107. Electric Power Drill for Underwater Operations: 1- ship sheathing; 2 - pawls for gripping the pins; 3 - spring; 4 - pin; 5 - lateral support; 6 - current-conducting cable; 7 - crossbar; 8 - crosspiece; 9 - electric motor; 10 - post; 11 - handle; 12 - reducing gear; 13 - spindle with quickly-replaceable chuck; and 14 - drill.

For driving the pins in or for punching holes, the gun is /174
loaded as follows. Into the muzzle attachment, we insert the spacer bushing 8 and two fiber linings 5. Using a wrench, we then turn the muzzle attachment as far as it will go into barrel muzzle 9, Into barrel 9, from the side of the breech part, we insert the

cartridge with charge 11 including the pin (or punch), selected according to the thickness of the steel which is being punched. Then breech 12 is also tightened to the hilt with a wrench.

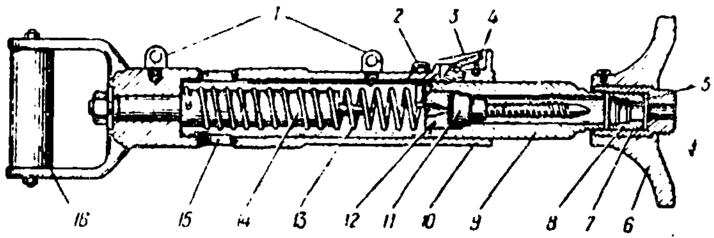


Fig. 108. Underwater Hole-Punching Gun (UHPG): 1 - lugs; 2- safety unit; 3 - catch; 4 - spring; 5 - lining; 6 - tripod; 7 - nuzzle attachment; 8 - spacer bushing; 9 - barrel; 10 - frame; 11 - cartridge containing charge and steel pin or punch; 12 - breech; 13 - firing pin spring; 14 - firing pin; 15 - hole; and 16 - handle.

The assembled barrel 9 is inserted in frame 10 of the gun as far as the catch, indicating that barrel 9 is in place. (In Fig. 108, we have shown the load with the pin). At the end of muzzle attachment 7, we place tripod 6, supporting the perpendicular position of the pin and preventing it from become skewed. Barrel 9 is pressed closely against the sheet which is being punched; using his left thumb, the diver presses on safety catch 2 and with abrupt pressure from his right hand on handle 16, he quickly moves the gun frame 10 forward; at this time, firing pin 14 ignites the percussion cap of the load and the shot occurs.

The pin is ejected from the cartridge and, passing along the bore of barrel 9, with its pointed end it punches the sheet and becomes wedged in it.

During the punching of holes in a metal sheet, the firing is accomplished similarly. The barrels are loaded at the water surface and are lowered to the diver in a readied form. The diver inserts the loaded barrel 9 into frame 10 of the gun and fires the shot. /175

The hull repairman's hand tools are quite diversified. These include a hammer, mallet, chisel, feeler gage for checking clearances, various wrenches and so forth. There is nothing special to be said concerning them and hence we do not include their description.

# CHAPTER 9

## REPAIR AND ELIMINATION OF LEAKAGE IN THE OUTER SHIP HULL SHEATHING UNDER WATER

In the practice of the underwater repair of ships, we are fairly often required to eliminate the leakage in the outer hull sheathing, developing from the formation of cracks, pits, disintegration of the riveted and welded seams, and other damages.

### Section 45. Welding Up the Pits and Cracks

In connection with the prolonged operation of ships, in the hull sheathing and framing, pittings and cavities develop. The depth of the pits will usually vary in the limits of 1-5 mm. With a thickness of the sheathing and the walls of the framing profiles more than 4-5 mm, the welding in of the places damaged by corrosion and the filling of pits are performed without difficulty. If the sheathing thickness is less than 4 mm, we apply patches or duplicate sheets to the damaged places.

Prior to the welding, the pits are cleaned out with a wire brush and are scraped out with a chisel until the pure metal is showing. The welding in of the pits is accomplished with the same methods as in the beading of metal. The application of beads is conducted concentrically in several layers.

The welding is conducted according to the steps shown in Fig. 109. Each successive bead is made after a careful cleaning of the preceding one, so that one gradually fills in the cavity of the cleaned-out pitting. The welding is continued until the entire pit space is filled.

A frequent defect in a hull sheathing is also the formation of cracks. In the welded hulls, the bulging of the sheets often appears in the vicinity of the welded joints; this often leads to the formation of cracks in the welded joints.

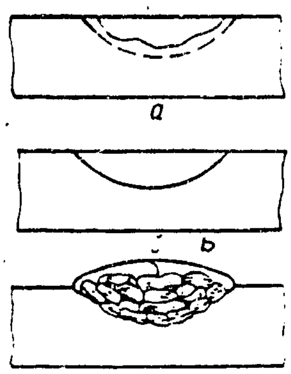



Fig. 109. Welding of Pits: a- flaw (defect); b- trimmed-out cavity; and c- welding.

If the cracks reach to the exterior and are small in extent, they are calked in with a chisel having a rounded side. However, if the bulging of the sheets is extensive and the joints have become disrupted, the sheets are first straightened, the bulge is smoothed out, the defective joints are trimmed clean, and then they are rewelded. The welding of a crack is conducted with a preliminary cleaning out of the paint, dirt, and fouling (barnacles). Depending on the thickness of the metal, an opening of it is developed, i.e. the chambers are removed at an angle of 30-35$^{\circ}$, as in the welding with a V-shaped finishing (Fig. 110).

If the crack is a through one, the finishing should also be done all the way through. The welding of such a crack is accomplished similarly to the welding of a butt joint. In order that the crack would not spread, the ends of the crack are drilled out or holes are burned

with the arc (where this can be accomplished). We then perform /178
its dressing and welding-in according to the steps indicated in Fig. 111. After the welding-in, if possible we perform the final welding of the crack from the reverse side.

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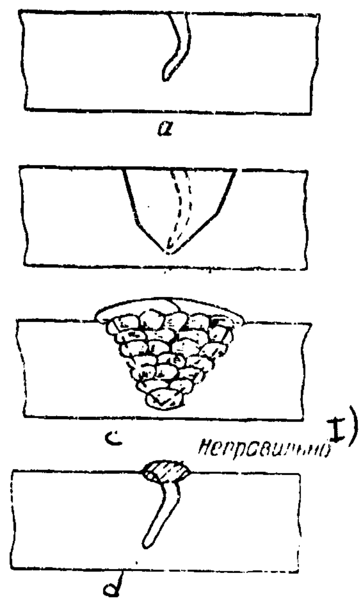


Fig. 110. Steps Involved in Welding in the Defects (of Blind Cracks): a- defect; b- dressing; c- welding; and d- incorrect welding. Key: I) Incorrectly.

## Section 46. Welding a Collar Around the Rivets /178

The elimination of the leakage in the riveted seams by welding under water is accomplished more successfully than in air since the intensified removal of the heat by the water does not cause a heating of the adjoining sections and does not disturb the tightness of the contiguous sectors of the riveted joint.

The damaged point is first cleaned of rust, scale and dirt; then the rivets and edges of the sheet in the damaged sector are built up with a narrow fillet weld with low current force and an electrode 4 mm in diameter. The welding around the rivets (Fig. 112) is conducted in two passes--i.e. the welder finishes half the perimeter at each pass. The beginning and end of the weld are extended to the side of the rivet by at least 5 mm.

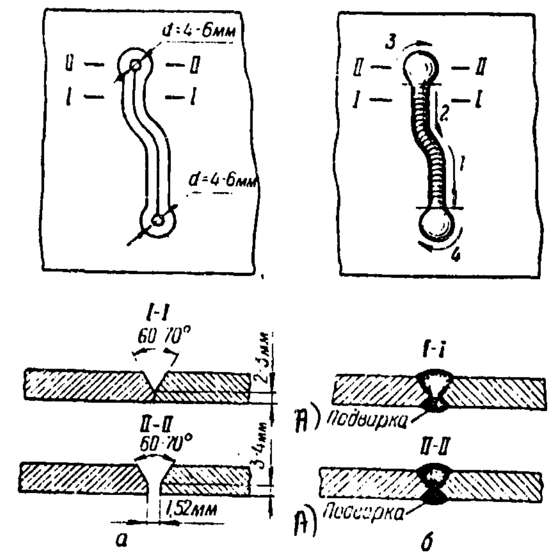


Fig. 111. Diagram Showing the Dressing and Welding in of a Through Crack: a- dressing; b- welding in; Arabic numbers and arrows indicate the sequence and direction of building up the seams. Key: A) Final (back) welding.

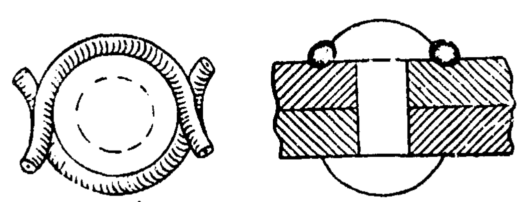

Fig. 112. Diagram Showing the Welding Around a Rivet.

### Section 47. Elimination of Leakage During Loss of Rivets

In case of the loss of an individual rivet without shifting the sheathing sheets, the tasks are performed in the following order: the diver, having searched from the outside along the side of the ship for the empty rivet hole, cleans it of rust, dirt and marine fouling and inserts a wooden plug into it. With the plug as a guide, the hole is found from within the ship and a standard rivet is inserted; the diver welds around the projecting part of its shank. In addition, in order to assure high-quality welding, the rivet is pressed from the inside against the side. Such a rivet is known as a "false rivet", since it lacks a second head.

The installation of a false rivet is accomplished in the cases when the hole's diameter exceeds 8-10 mm. If the holes are smaller, new rivets are installed and they are "cold-riveted" with hammers. For this purpose, after the insertion of the wooden plug, the diver is sent a holder and the rivets and, having replaced the plug with a rivet, he holds it during the riveting which is done from inside the hull. If the diver can not manage to maintain the support of the rivet by hand, he uses a bar.

If there is a shortage of rivets (riveting blanks), a pin (bolt) is inserted in the rivet hole; this is welded around in the same manner as a rivet.

After the completion of the welding tasks from the outside and the pumping of water from the compartment or the unsealing of the welding location, the bolt shank is welded around from inside the ship hull with low current force in order not to disturb other sectors of the riveted seam.

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The projecting portion of the bolt is trimmed off with a chisel or with the cutter.

In the event of the loss of several rivets and the shifting of the holes, we first line up the rivet holes and then we insert the false rivets.

In case of a significant shifting of the holes, in the place of the standard rivet with the round shank, we insert a special tapered rivet (Fig. 113) which assures the lining up (matching) of the holes. From inside the ship hull, such a rivet is pounded into the hole with a hammer or sledgehammer. After the rivet has been seated in place, it is welded around from the outside.

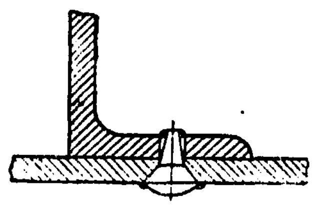

Fig. 113. Insertion of Tapered False Rivet.

In case of separation of outer sheathing from the framing and the divergence of the rivet holes, the diver cleans the holes and the slots between them of dirt, rust and marine fouling and inserts a special bolt with a tapered shank and a round threaded part at the end.

The tapered bolt is driven in with a hammer and the holes are lined up; then, by turning a nut onto the threaded part of the bolt, the sheets are pressed together (or to the ship frame). This work is performed by two divers (or by one diver and a hull repairman, working inside the ship's hull).

If the holes have gotten out of line considerably, use is made of a special mandrel or bar with a tapered point on one end.

From the outside, the diver inserts the bar into one of the rivet holes, "delivers" the tapered end of the bar or mandrel to the proper hole in the second sheet or frame and, using it as a lever, brings the holes together.

When the holes have been aligned to some extent, from inside a tapered bolt is inserted or driven into the adjoining hole; with the aid of this bolt, the rivet holes are lined up and the sheets are pressed together. Then the diver inserts the rivets which are struck until the head spreads, or they are welded around. After all /181 the rivets have been positioned, the bolt is withdrawn and a false-rivet is inserted in its place.

In the case of extensive defects in the riveted and welded joints, when it does not appear possible to align the holes or to press the sheets together, the part of the weakened rivets contiguous to the defective sector is replaced by false rivets and a patching sheet is applied to the defective sector.

## Section 48. Repair of Small Holes in a Ship Hull

In the case of slight damages to the hull, e.g. from bullets etc., for temporary repair wooden plugs are utilized. In the event of many small holes and when opportunity is lacking to install a patching sheet with the application of electric welding, the diver takes a set of wooden plugs along when he dives, and he uses them to plug the holes.

This repair is temporary. Upon the ship's return to its base, the wooden stoppers are extracted, and the holes are repaired by welding, with the installation of false rivets, and the application of patches or cover plates. The choice of the repair method depends on the actual sizes of the holes and the working conditions.

## Section 49. Underwater Repair of Dents in Outer Sheathing

The dents in a ship hull can be of various sizes and often extend beyond the limits of the frame spacings. If a dent extends across several successive frame spacings and does not have any ruptures, a duplicating sheet is applied. However, if the dent does not extend beyond the limits of 1-2 spacings, it is repaired from inside the ship with jacks or from the side with the utilization of special clamps and bolts.

Repair of the dents is conducted from the ship's side as follows. From within the ship in the deformed sheet of the outer sheathing, we drill a hole and insert a bolt. From outside,the diver attaches a clamp to the bolt; the grips of this clamp rest on the adjoining frames and a nut is turned on. From inside, under the bolt (to avoid leakage) a packing washer is installed as well as a steel spacing disk with a thickness not less than that of the sheathing, which (disk) /182 during tightening of the nut from outside transmits a force over a large area. The installation of the spacing disk is mandatory; otherwise, during the tightening of the nut, the bolt will rip out of the sheet, and a torn hole will be formed. In proportion to the tightening of the nut, the dent is smoothed out until fully removed. The nut is then released and the device is disassembled.

In the place of the extracted bolt, a rivet is inserted and welded around. If no rivets, bolts or other stems with a head are available, before knocking the bolt out, a small patch is prepared which is installed and welded in place as we have explained below.

### Section 50. Underwater Repair of Holes in Outer Hull Sheathing

The repair of holes is the most complex and difficult task requiring special training of the diver-ship repairmen.

## Preparation for Repair of Holes

The preparation for the repair of holes depends on their dimensions and location. Based on the obtainment of data from the diver's investigation, a procedure for performing the work is developed.

The first step is to outline with a cutting tool, the area for removal of the damaged sheets and elements of the framing. This marking is done on the undamaged sectors of the sheathing and framing in order to remove not only the ripped sections but also the wrinkled and bulged elements and creases, the straightening of which is difficult when underwater conditions are involved. This is established in each case by proceeding from the actual conditions and the nature of the damages.

After the marking, the next step is to remove the damaged parts with the aid of oxy-electric gasoline-oxygen or electric arc cutting (Fig. 114). If these means are not available or the sheathing is not very thick, the work is done with a chisel.

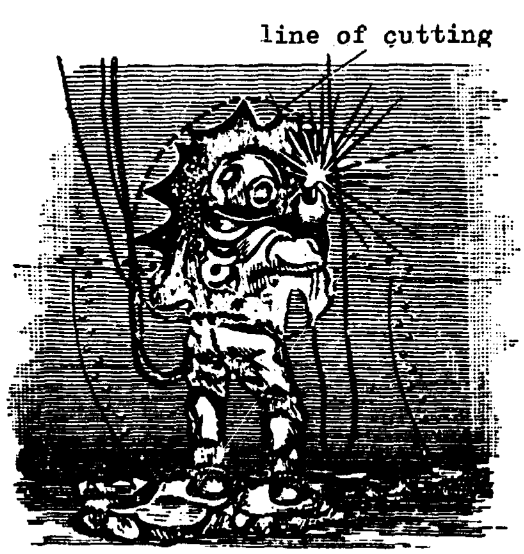


Fig. 114. Flame Cutting of Damaged Sections of Sheathing According to Marking, for Sealing a Ship's Hull Prior to Raising (Salvaging).

Then the surface which is to be covered with a patch or a duplicating (cover) sheet is cleaned of marine fouling, dirt and rust, the hole edges are cleaned or trimmed off with a chisel; the burrs and rough spots are cleared off. As much as possible, the hole /183 is imparted the form of a rectangular opening to facilitate the subsequent work involved in making a pattern.

Making the Pattern

In principle, the tasks entailed in making patterns (templates) from the outlines of the ship hull under water do not differ from similar tasks performed at the surface; however, under water they are performed under more difficult conditions. It is recommended that the tasks be performed by two divers working from a scaffold.

Copying the patterns is accomplished by three methods. If the hole is small, i.e. within the limits of 1-2 frame spacings, copying the pattern is accomplished with the aid of a lead covering sheet and a mallet. The sheet is placed on the hole and is pounded around its edges. Thereby the lead sheet acquires the hull's camber in the damaged place.

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If a lead sheet is unavailable, the pattern is copied with the aid of wooden boards and scribers. The boards are pressed in succession along the perimeter toward the edges of the hole, and with the scriber, the outline of the hull lines is drawn (Fig. 115). For copying the outlines in such a manner, at least four boards are needed. Then on the surface in reference to the marked curves of the hull camber, the boards are cut off and a template (form) is prepared with them.

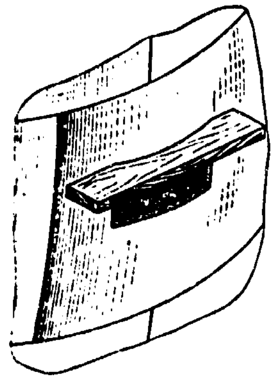

Fig. 115. Copying a Pattern with the Aid of a Wooden Board.

If the hole is larger than 1 $m^2$, for copying the outlines, use is made of a special device, i.e. a "comb" consisting of an oak beam or a metal strip equipped with screws. Into the wooden beam with a section of 40 X 60 mm and with a length of 1.5-2 m, nuts are inserted, while in the metal strip, we drill and cut openings with a diameter from 9-12 mm. Screws are turned into these holes or nuts. On the ends of the beam or strip, eye bolts are incorporated for suspension on ropes.

Having determined the section from which it is necessary to take the pattern, we indicate it by using a special chalk to mark the sheathing. The "comb" is lowered on ropes, the diver sets it in sequence perpendicularly to the sheathing (shown with a broken line) (Fig. 116) and tightens the screws until they come in contact with the hull sheathing. In such a position, the "comb" is raised. The location of the screws by their points are transferred to the board which is laid by its edges against the beam. Based on the transferred points, we draw a curve for the sheathing's camber in the given section. The "comb" is then lowered once again to the diver and he repeats the operation in another section. A pattern (template) is prepared from the curves.

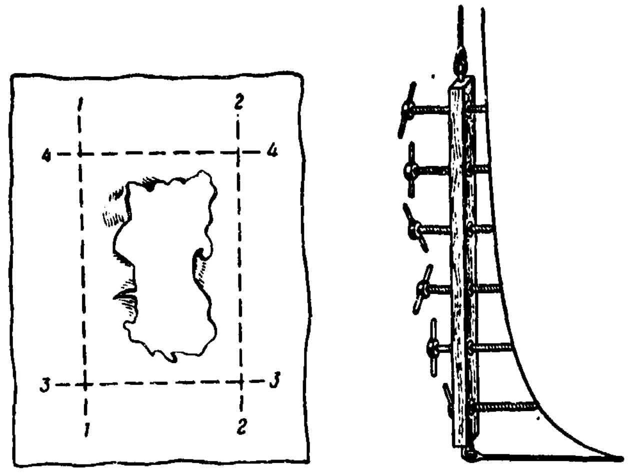


Fig. 116. Copying the Camber of the Ship Hull Outlines with the Aid of a "Comb". The numbers refer to the sequence of copying the outlines' camber.

Instead of the "comb" for copying the hull's camber, we can use the "harrow" (Fig. 117) with the aid of which the camber is established immediately over the entire damaged surface of the side and not just for one section. The principle of the "harrow's" arrangement is the same as for the "comb". A wooden frame (Fig. 118) is made according to the measurements derived.

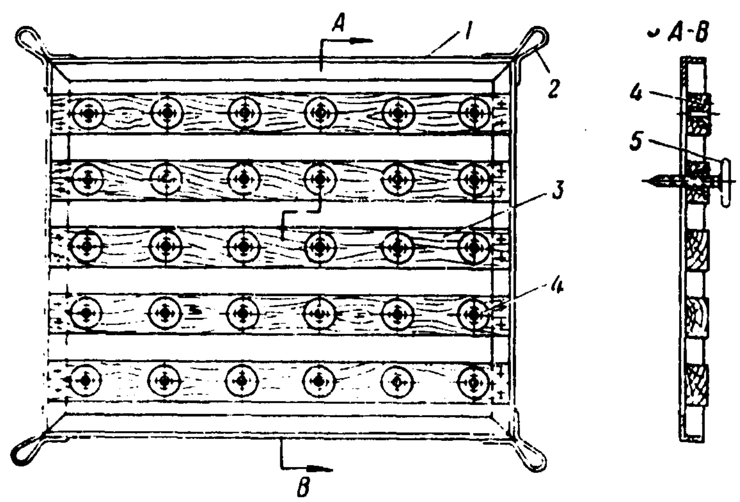


Fig. 117. "Harrow" Device for Copying the Camber of Ship Hull's Outline: 1- frame; 2- eyebolt; 3- beam; 4- bushings; 5- measuring bolt.

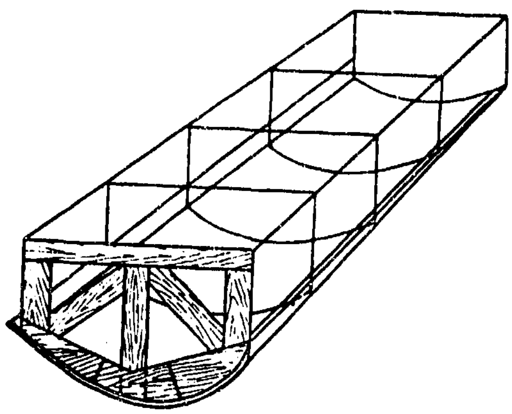

Fig. 118. Frame (Pattern) for Preparation of a Patch.

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For reliability and the high-quality performance of the tasks, it is necessary to prepare a frame in all cases of copying the patterns. The patch or covering sheet prepared from the pattern is checked and fitted into place.

In the event that the diver's approach to the damaged side is impossible, the copying of a pattern is conducted on the basis of using a matching part of the undamaged opposite side. A pattern is also copied for the preparation of the so-called "inserts" in place of the removed framing elements. If this pertains to the frames, such "inserts" are often called "false frames" (Fig. 119).

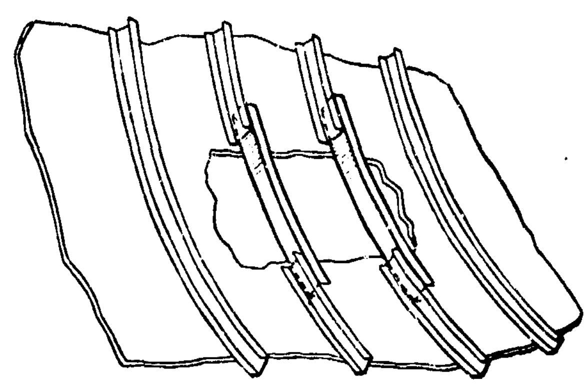

Fig. 119. Installation of "Inserts" (False Frames).

Depending on the nature of the damage, the installation of the patches is conducted with or without restoration of the framing. The duplicating (covering) sheets are installed on top of the sheets in the outer planking.

The installation of small patches (up to 200 X 300 mm) does not present any difficulties. The patch (without a pattern) is fitted in place and it is provided with a small groove (if the patch is small, no groove is made). The patch should overlap the edges of the hole for a distance equalling five times the sheet's thickness, but not more than 150 mm. Initially, the diver places the patch on clamps, and then welds around it with the back step or tack-welding method.

The patches with a dimension of about 400 X 500 mm are installed with pressure against the hull planking with the aid of welding clamps and oak wedges (Fig. 120). In the remaining places, the patch is fitted with light blows from a sledgehammer.

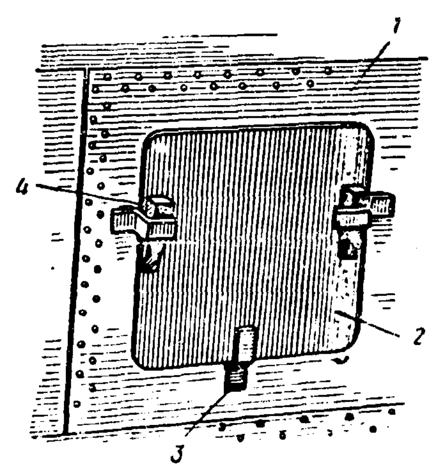


Fig. 120. Installation of Patch with the Aid of Clamps and Oak Wedges: 1- ship planking; 2- patch; 3- clamps; and 4- oak wedges.

Any kind of welding in around through holes in the ship's outer planking and the welding around patches placed on holes is conducted under uniform pressure, i.e. with water pressure being the same both from outside and inside the hull. If the holes are small, the sealing is achieved by the placement of a patch from within the hull; in the case of large holes, the tasks are conducted with a flooded compartment, from which the water is pumped only after the completion of the welding operations.

/188

Installation of patches with restoration of framing is accomplished by two divers, i.e. by a hull repairman and a welder. The "inserts" and patches prepared in the shop are carefully checked at the repair point and carefully fitted. For making the work easier, during the fitting and installation the "inserts" and patches are hung on ropes from the upper deck by eyebolts welded to them for this purpose.

The "inserts" are fastened by clamps to the framing of the ship hull; they are then tack-welded and finally are fully welded in place. After the mounting and tack-welding of the "inserts", the patches are installed. When conditions permit, the "inserts" are only tack-welded under the water, and they are fully welded from within the hull after the installation and welding around of the patch or of the duplicating sheet, and the pumping of the water out of the compartment.

The patches are made of low-carbon steel with a thickness of not over 5 mm. It is easy to fit such a patch on the spot, and it can easily be imparted the camber of the ship hull. The patch is lowered on ropes to the diver, is hung on a pin welded on or delivered with a hole-piercing gun, and is tightened with a nut. Using a hole-piercing gun, we then install the remaining pins around the perimeter and in the holes drilled in the patch. The holes in the patch serve as guides for the installation of the pins.

Nuts are turned onto the pins which are positioned and the patch is pressed against the planking (sheathing). After this, the patch is tack-welded at first in one or two places and is fitted in such a way that along the entire edge, the clearance would not exceed 2 mm. Further, the patch is tack-welded by sections of 10-50 mm each every 300-400 mm and is welded with a back-step weld (Fig. 121).

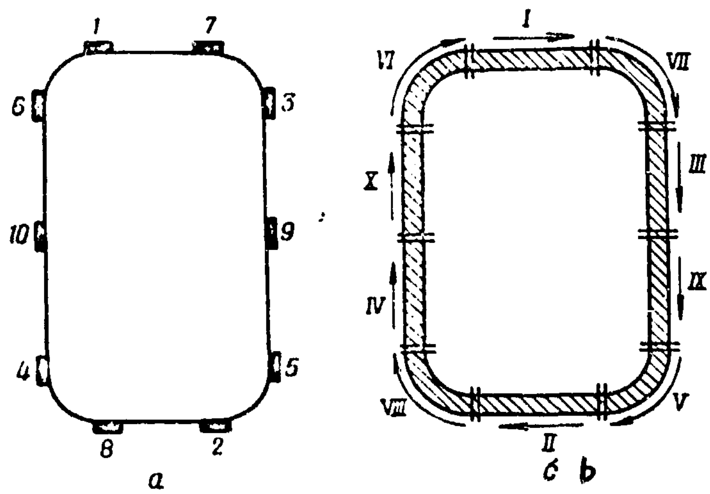


Fig. 121. Sequence of Tack-Welding and Welding of Rectangular Patch to Ship Hull: a- sequence of tack-welding; b- sequence and direction of welding; 1 - 10 = sequence of tack-welding; and I - X = sequence of welding; the arrows indicate the direction of welding.

To avoid the application of vertical and especially of overhead joints, the patches are made triangular, rhombic, trapezoidal or rectangular in form and are installed in the planking (sheathing) in such a manner that there would not be any overhead welding. The dimensions of the patches are given in Appendix 24. We recommend rounding the corners of the patches to avoid the concentration of stresses.

A method does exist for replacing the overhead welding with horizontal welding. The gist of this idea consists in welding a bar (with diameter of 10 mm and more) of rounded or square section (Fig. 122) in advance, along the place of adhesion to the planking, of the lower edge of the patch or of the covering sheet.

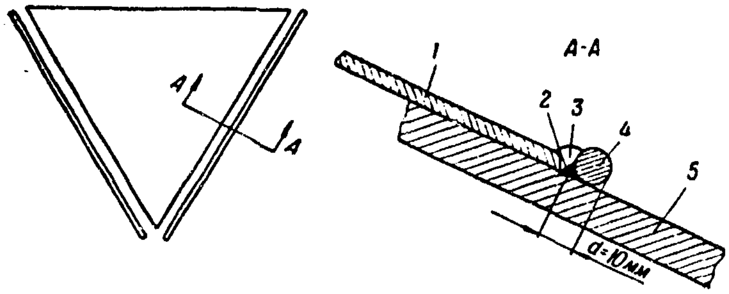


Fig. 122. Welding Around a Patch with Auxiliary Rod: 1- patch; 2- welding seam of rod; 3- welding seam of patch; 4- steel rod; and 5- ship's planking.

Then on this bar, as on a rack, we install the patch, tack-weld /189 and weld it; however, the welding of the lower edge has already been conducted in the horizontal (downhand or semivertical) position and not in the overhead position. After welding around the patch, the nuts are loosened and the projecting parts of the pins are cut off flush with the patch and are welded around.

If there is no chance to perform electric welding on the ship, /190 a temporary patch is placed on the pins with a rubber lining. In this operation, the nuts are tightened evenly around the perimeter in order to prevent infiltration of water. The mounting of the patches on the pins is possible only if the outer planking is at least 8 mm thick.

The large patches and the duplicating sheets are usually installed under pressure from special cleats. After the installation and tack-welding of the "inserts" around the perimeter of the patch or sheet (regressing slightly from it), we weld bolts to the planking or we drive pins in with a hole-punching gun. Short strips are hung on the bolts and they are tightened slightly with nuts.

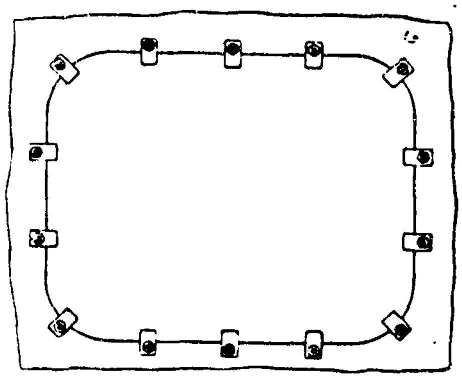

Fig. 123. Installation of a Large Patch with Aid of Pressure Strips.

The patch is lowered on ropes, is positioned between the bolts and is placed over the hole. Eyebolts are welded to the patch for convenience in the work. The initial pressure of the patch against the ship hull is conducted by one or by two underkeel slings. After this, the strips are placed on the patch (Fig. 123) and the nuts are tightened, with observance of uniform clearance.

One should never try to fit a patch with a hammer. When necessary, under one or two adjacent nuts, we place extra washers and then conduct the tightening until the required gap is obtained. After fitting and final compression, the patch is tack-welded and then welded around. Upon completion of the welding, the strips are removed and /191 the pins and assembly eyebolts are cut away.

The duplicating sheets are also placed over a large hole and when necessary, the hull is reinforced, i.e. in preparing a ship for a cruise in the northern latitudes under ice conditions.

After completion of the tasks, water is pumped from the flooded compartment and the welding of the framing elements is performed. The winch and other equipment are put away only after checking the compartment for leakage and the correction of all defects detected.

The metal patches are mounted on a rubber lining. The technique and sequence of the procedures are the same as in the installation of the temporary patches. Other methods also exist for installing the patches and duplicating sheets but they are merely modifications of those which we have described.

## Devices

The devices for the accomplishment of the hull repair tasks under water are the same as those utilized at the surface. In underwater ship repair, use is made of the all-purpose device, the "fish's tail" and a clamping device for large patches and cover sheets.

The "fish's tail" device is utilized for fastening, compressing, and straightening the planking sheets of the hull. When necessary, the support part of the device is tack-welded by electric welding to the hull planking or it utilized as a clamp without welding the support part to the planking sheet (Fig. 124).

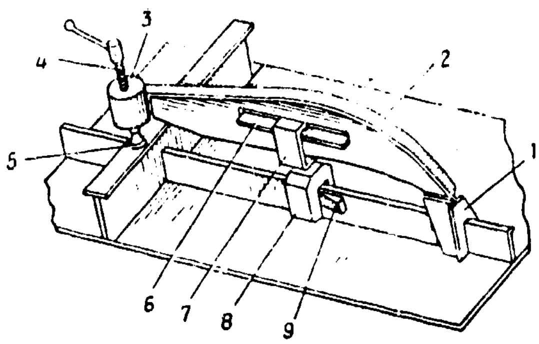


Fig. 124. Utilization of "Fish Tail" Device for Compressing the Framing Elements to the Planking without Welding the Support: 1- support; 2- housing of device; 3- nut; 4- screw; 5- support; 6- guiding strip; 7- small clip; 8- clamp; and 9- wedge.

In the installation of large patches with a measurement of 1500 X 2000 mm or of cover sheets on smooth sectors of the ship hull, we use a special pressurizing unit (Fig. 125). This clamp consists of two guiding angle pieces 1, tack-welded to the planking parallel to one another along both sides of the hole, and of a mobile strip 5 with slides 2 and clamping bolts 4 with linings 5.

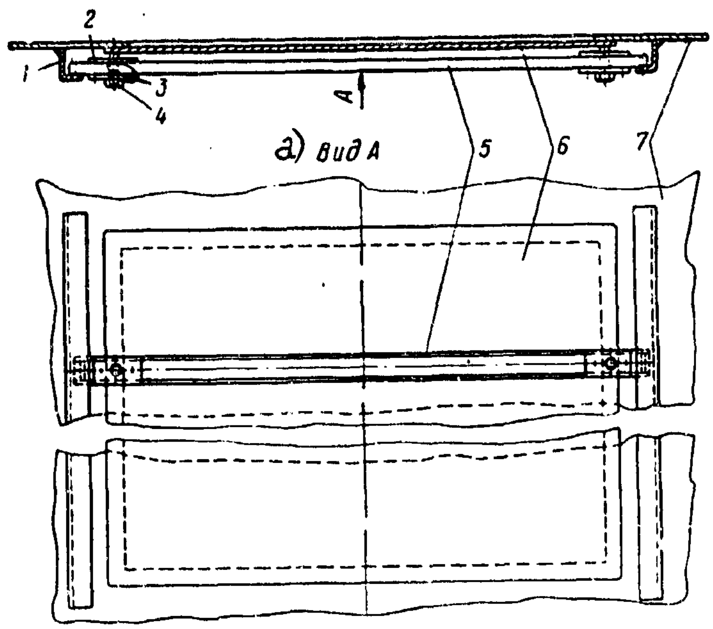


Fig. 125. Clamping Unit for Large Patches or Cover Sheets: 1- guide corner brackets; 2- slides; 3- strips (linings); 4- clamping bolts; 5- mobile strip; 6- cover sheet; and 7- planking. Key: a) View A.

After the delivery of cover sheet 6 and its initial compression by the underkeel slings, between the sheet and the corner guide bracketsl, there is inserted the mobile strip 5. Having determined the location of the mobile strip and having placed the slide blocks a along the edges of the patch or of the covering sheet according to their dimensions, the diver tightens the bolts 4.

Depending on the dimensions of the patch, for its uniform fitting against the hull's sheathing, we apply 2 - 3 moveable strips.

After the fitting, we perform the tack-welding and a subsequent welding of the patch.

## Section 51. Connection of Framing with Sheathing and Welding the Sheets of Great Length

In the underwater repair of ships, it is often necessary to weld sheets of the outer planking to the framing elements of the ship hull. The welding of the planking to the solid elements of the framing (the stems, keels) presents a definite difficulty, since the planking (sheathing) is relatively thin.

The tasks involved in the replacement of a damaged sheet of the outer planking begin with its removal. The framing is then cleaned of dirt and scale. According to a sketch or template taken from the opposite side, a new sheet is prepared. The fitting and installation of the sheet is achieved by one of the accepted methods, depending on the location and dimensions of the sheet. The new sheet is tack-welded and then welded.

The welding is conducted with uniform melting of the metal in the framing and the sheet of the planking. For this purpose, the electrode is held longer on the framing than on the planking. The side of the fillet weld incident to the sheathing would be smaller than that incident to the stem or the keel.

For an improved adhesion of the sheathing to the bar keel or to the stem, we recommend the use of electric riveting (Fig. 126).

The welding of sheets longer than 700 mm is conducted by two divers. It is necessary to install the sheets with allowance for subsequent shrinkage. To avoid the overlapping of the sheets onto one another, the beading of the sheets is conducted. The welding is done by sections with observance of a definite sequence of building up the joints (seams).

During the welding of bilges (and in a sunken object--of the bulkheads and decks during their sealing) and of the sheathing of a ship hull, the build-up of the seams is conducted intermittently or in a back-step sequence (depending on the actual working conditions). /194

The welded joints are so arranged that they are separated from the frames by a distance equalling one-third the length of the frame spacing.

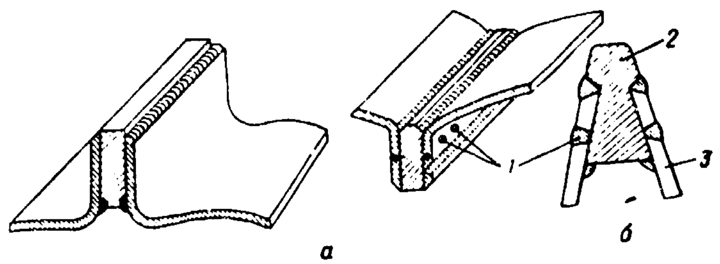


Fig. 126. Welding of Sheathing:
a- to the bar keel; b- to the stem; 1- electric riveting; 2- stem; and 3- sheet of outer planking.

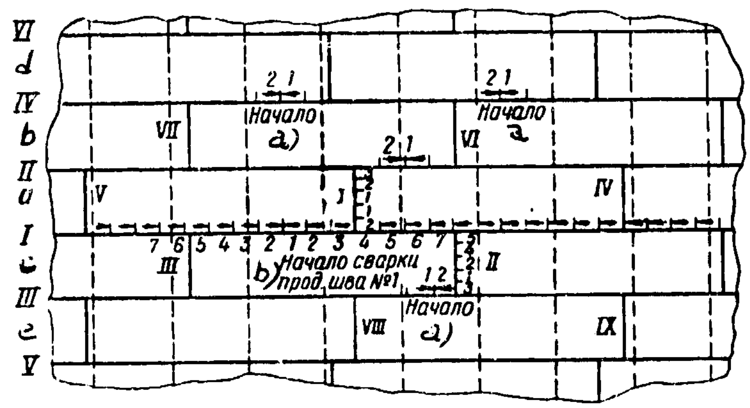


Fig. 127. Sequence of Applying Seams in Replacement of Several Sheets of Outer Planking: the letters a, b, c, d and e refer to the order of assembling the strakes; the Roman numerals I - IX indicate the sequence of welding the joints and slots; the Arabic

numbers 1-7 signify the order of building up the seams in the joints or slots. Key: a) beginning; b) beginning the welding of longitudinal seam No. 1.

In case of the replacement of several sheets of the outer sheathing, in the adjoining strakes or in the installation of the covering (duplicating) sheets, we first perform the assembly and tack-welding; only after this do we perform the welding of the joints in staggered order and then the welding of the sheets in each strake with one another. The general direction of the welding is from amidships toward the ends of the ship, or from the diametral plane (DP) towards the sides. We have shown in Fig. 127 the order of applying the seams in case of replacing several planking sheets in the adjoining strakes; with the letters a, b, c, d and e we have indicated the order of assembling the strakes, with Roman numerals, the sequence of welding of joints and grooves, and with Arabic numbers, the order of applying the seams in the joints and grooves. The beginning of welding of the longitudinal seams has to be performed in a direction away from the joint.

## Section 52. Underwater Concreting

Concreting is conducted only when there are no other means on the ship of repairing the holes, and it is situated in autonomous conditions. Two methods exist for sealing a ship hull with concrete. Treating with concrete in the drained compartments, i.e. after the closing of a hole with a box-type patch, is accomplished in the same way as at the surface. In this instance, the diver places the box-patch; water is pumped out of the compartment; a mold is built around the hole, and a drainpipe is installed for pumping out the incoming water so that the concrete would not be washed out.

The method of underwater concreting, known as VSP (vertically shifting pipes) has been developed by Prof. V. I. **Dmitriyevskiy.** The gist of this technique consists in the idea that ahead of the pouring location, the concrete would remain isolated from the water and would not be eroded. For this purpose, use is made of a pipe with a receiver at the top, having conical buckets with an opening bottom or a concrete pumping arrangement.

The place where the concrete is to be poured is cleaned of dirt, rust and oil; the hole is backfilled with sand-filled bags or with iron bars, upon which we place coarsely-woven cloth in layers, or sand bags, or a wooden box-patch, and then the wooden form is installed. After this, a pipe is lowered, and through it, the mixed cement is delivered. The pipe is moved parallel to itself and the cement layer is distributed over the damaged section of the sheathing. The pipe's end is buried in the cement so that in case of an interruption in the supply of concrete, water would not get into it (Fig. 128).

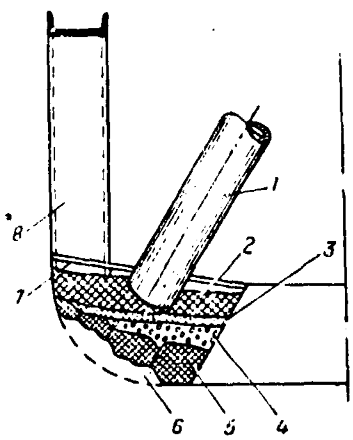


Fig. 128. Concreting Under Water: 1- pipe for delivery of concrete; 2- layer of concrete; 3- layer of sand; 4- cinders; 5- sand bags; 6- hole; 7- form; and 8- side of ship.

As the concrete settles, the pipe is raised. The concrete is delivered immediately for the entire height intended, thus covering the hole and the undamaged sections of the sheathing. The concrete is carefully levelled out and puddled so that no air holes would remain. In case of the underwater concreting, use is made of the aluminiferous or fast-hardening brand 400 or 500 Portland cement; sometimes we add calcium chloride (2-10%) or liquid glass to it. The composition of the concrete is: 1 part cement, 1 part gravel and 1-2 parts sand. The dry mixture is diluted with fresh water to the consistency of thick paste. To each 10 buckets of cement, we add 6 buckets of fresh water.

After the concrete has hardened, the water is pumped from the compartment. Among the advantages of underwater concreting, we should include the simplicity of performing the work. The concreting can be done by manual means under autonomous conditions and does not require the application of power. A disadvantage of the concreting is the slow (5-7 days) setting, considerable weight and brittleness of the cement finishing. In the operation of the engine and of other mechanisms, the ship's hull experiences continuous vibration, leading to the settling and chipping of the concrete.

## Section 53. Repair of Wooden Hull While Afloat

A wooden hull is rarely repaired under water and at the detection of water leakage, one is limited to the temporary installation of metal covering plates.

After inspecting and cleaning the sheathing seams, the diver tamps down the old calking and tightly calks the defective seams with unravelled strands of tarred rope. The prepared rolls of rope /197 are lowered to the diver in a net or a weighted bucket. The hammer is tied to a winch or to the diver, and a metal holder is made on the handle.

Leakage through the hull is sometimes detected from the outside; for this, the diver is lowered a sawdust-filled bag; he scatters the sawdust near the place which has been repaired. If leakage has been left, the sawdust will be drawn into the seams in the sheathing. This technique is utilized in the diver's inspection of a wooden ship hull for leakage. If the filtration of the seam is slight, the sawdust plugs the openings in the seams; it then expands, and promotes a reduction in the leakage.

If the filtration is extensive, we install thin metal covering plates (1.5 - 3 mm). The sheets (plates) are trimmed in accordance with the previously taken measurements and are fitted by pounding into place. Holes are drilled or punched along the perimeter of the sheet. The fitted sheet is then painted or puttied with a red lead paste and is painted on the exterior. After this, according to the sheet's size, one takes heavy cloth impregnated with red lead, dries it in the air and sticks it to the covering sheet.

The sheet with the cloth lining is lowered to the diver and fastened to the faulty section of the sheathing to the wooden hull. Nails are driven around the perimeter of the covering plate in staggered sequence at least 40 mm apart. It is necessary to see to it that the nails are pounded into sound sections of the sheathing and that they hold tightly in it. The inspection for the leakage is conducted by the conventional method.

# CHAPTER 10

## INDIVIDUAL TASKS PERFORMED ON A SHIP'S HULL UNDER WATER

### Section 54. Welding on Ship-Hoisting Lugs Under Water

In the ship salvaging (raising) practice, use is made of the ship-hoisting lugs having a lifting capacity of 80 and 100 tons; they serve for the attachment of slings to them.

The lug (Fig. 129) consists of a main sheet or base of trapezoidal form with openings for receiving the electric rivets, two knees (brackets) and reinforcing ribs into which a plug is inserted for attaching a cable and a guide roller.

The place for welding the lugs to the ship hull is chosen on the basis of the design calculation, with allowance for the framing strength. It should not have dents, breaks or riveted seams. The site for attaching the lug is carefully cleaned and the base of the lug is given the camber according to the hull's generatrix (based on a template). Before installing the lug, at the location of the base's lower edge, a bar is welded on, as is the practice in the welding of patches.

The lug is hung on pins or bolts previously mounted or welded to the ship's hull and then tightened against it with bolts and clamps. After this, the lug is tack-welded in sections every 30-40 mm, and is then fully welded with a back-step seam along the base's perimeter (Fig. 129).

Welding a lug with a lifting capacity of 80 tons is conducted with a dual seam, with cleaning of slag and spattering, while the lug with 200 ton capacity is made with a triple seam. The first seam is applied with electrodes having a diameter of 4 mm while the subsequent ones are made with electrodes 5 mm in diameter.

To increase the welded joint's perimeter, in the lug's base there are 8 openings for inserting the electric rivets which are welded only in the lower half (Fig. 129, cross-hatched). The overhead and semi-overhead joints are needed only for technical reasons and do not enter the strength calculation.

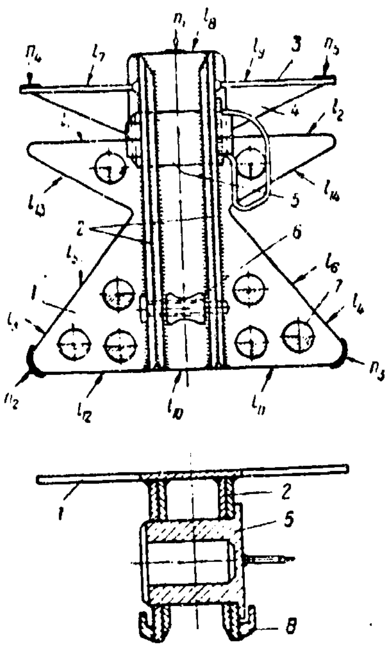

Fig. 129. Ship-Hoisting Lug: 1- main sheet (base); 2- reinforcing ribs; 3, 4- brackets; 5- plug; 6- rolls; 7- opening for electric rivets; 8- retaining unit; $n_1$ - $n_5$ = sequence of tack-welding the lug; and $l_1$ - $l_{14}$ = welding sequence.

## Section 55. Installation of Coamings Under Water /200

In performing the ship salvaging activities, it is sometimes necessary to weld coamings to the ship hull; these serve as a base for the shafts, cofferdams and the like. A hole is cut in the ship hull for the installation of the coamings, bases of shafts and other parts. Based on the pattern made, the coaming's end is imparted the configuration of ship hull camber in the place of its (the coaming's) installation, with a slight tolerance of 50 - 100 mm. The coaming is then lowered to the diver in such a way that its upper flange would be horizontal. The coaming is lowered onto the ship hull and the diver fits it into place; using a marking gage, he outlines the hull camber on the coaming.

According to the marking made by the diver, the coaming is undercut at the surface; it is suspended on a rope and the diver installs it in place. It is desirable that this work would be conducted by two divers--by a hull repairman who makes the fitting in place and installs the coaming, and by a welder who performs the tack-welding and the complete welding with a permanent continuous seam.

To avoid bucklings, the welding of the coaming is conducted alternately by sectors, with use of a back-step joint. Around the outside perimeter, we apply two fillet welds, while around the inside one, we apply one weld. If on the outside, the welding has been conducted from right to left, around the inside perimeter the welding is performed in the opposite direction.

### Section 56. Removal of Damaged Sections During Underwater Conditions

The separation of damaged sections is conducted when eliminating leakage, installing plates and patches on a hole in the hull's exterior sheathing, and so forth. Along the intended line of cutting, we clean the section of the exterior sheathing of marine fouling and paint for a width of 20-30 mm. Then to the ship's side along the proposed cutting line, we fit and weld a guiding strip or template, and the cutting of the damaged components is performed.

If there are major damages having caused the collapses and disruptions of the systems (e. g. as a result of an explosion), we conduct a gradual cutting and removal of the individual pieces of the damaged parts, preceded by attachment of ropes. At this time, the diver's work is monitored continuously.

If it is not possible to attach a sling to the part being cut off, two holes are cut in it; through these, we run a cable fastened at the surface. First we remove the exterior pieces and then we gradually reach the parts located on the inside (within) the compartment.

### Section 57. Dismantling (Disassembling) the Sunken Ships for Metal

The dismantling of sunken ships for metal is the most complex of such tasks under water. The ship designs consist of various profiles (including molded ones) and of diversified sections (plates, channel irons, angle brackets, zee-beams, flat iron, packets etc.).

If the object is large, it is first separated into sections by blasts from a charge having a cumulative effect. We sometimes use combined dismantling, i.e. the combination of fire cutting with explosions. In this case, using explosions we break down the longitudinal and transverse connections and other elements of the framing (beams, bulkheads, stems etc.), while with oxyelectric or gas-oxygen cutting, we disassemble the floors, decks, side sheathing, and so forth.

The cutting is done first in the places which are difficult to reach. The cutting line is drawn in such a way that during the removal of the part, the length and number of cuts would be minimal. For drawing the hoses through and for the diver's access, the cutting of holes in the sunken object is performed first.

The cutting sequence is selected so that the parts being removed can be hoisted readily to the surface and so that they would not fall onto the diver-cutter, and would not damage his air line and signal rope.

Since during oxyelectric cutting, a large amount of gases is released (hydrogen, oxygen, methane etc.), forming an explosion-prone mixture, ventilation is required during operations in closed compartments. For this purpose, in the upper levels of the compartment, a hole is cut and air is supplied via a hose, or a gas-diverting hose connecting with the surface is furnished.

If the compartment design requires the performance of /202 cutting in all the spatial positions, we conduct the cutting first in the downhand, then in the vertical, followed by cutting in the overhead position. With such a sequence, the dismantled and weakened joints will always be located below the diver.

The cutting conditions are chosen on the basis of the maximum section of the element which is being cut off. During the cutting of round sections (e. g., of the propeller or intermediate shaft, of the davits, etc.), the head of the cutter or electrode is set at an angle of 20-30° to the surface which is being cut and when possible, the part is turned. In case of the multi-tiered disassembly of ships, the general direction chosen is from above downward, while inside the compartments, it is mandatory to cut from below upward.

Section 58. Taking the Ordinates of Ship Hull Outlines While Afloat

In the event of the absence of a dock or theoretical sketch of the hull, for framing in the space between the double bottom, it is necessary to restore the drawing of the dock operation by way of taking the ordinates of its hull outlines in the places of the proposed location of the spacings between the double bottom while the ship is afloat.

The essential idea of the method is that, placing a beam (bar) under the keel in the marked section of the ship hull and having adopted it (the bar) as a base, we conduct measurements of the distance of its points from the sheathing (the ordinates) in the previously marked sections of the hull. Measurements of the ordinates in the underwater portion of the ship hull are conducted by the diver.

Devices for Plotting the Ordinates of the Hull Configurations

For plotting the ordinates of the hull's submerged part while the ship is afloat, we utilize: an underkeel beam, wooden rods, sounding rods, measuring rulers of varying length, ballast and a steel cable with a diameter of 8 mm for positioning the beam.

The underkeel beam (Fig. 130) is a sectional cruciform rigid unit made of four pine or fir beams with a section of 90X100 mm, held together by nails or spikes. The beam's length is chosen in relationship to the width of the ship hull's cylindrical part. With a hull width up to 10 m, the beam is made shorter by 1 m than the ship, while with a width greater than 10 m, the beam is made shorter by 2 m. /203
Eye bolts are screwed into the ends of the beam. The top edge of

the beam is planed and the beam is coated with a light waterproof paint; in the middle a mark is made with dark paint, corresponding to the diametral plane (DP) of the ship. In order that the beam would have negative buoyancy, ballast is attached to it, divided evenly over the beam's length.

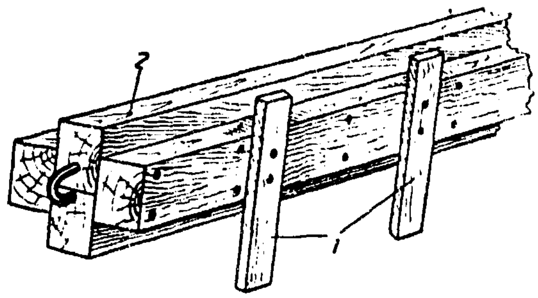


Fig. 130. Underkeel Beam for Taking the Ordinates of Hull's Configuration: 1- rods; and 2- beam.

The rods with a measurement of 250X40X15 mm are made of pine boards, are planed, coated with a light waterproof paint and are then nailed on in line with the mark on the underkeel beam, symmetrically along both sides from the DP mark. The rods' upper edge should be flush with the beam's top edge. The rods act as guides in the application of a measuring ruler during the conduct of the measurement and establish the positioning of the ruler. For each actual case, the location of the rods along the beam differs, and is determined by the ship's measurements.

The measuring rules are made of oak with a section of 40X20 mm and lengths of 1, 2 and 3 m. They are utilized in the measurement of the ordinates. The rules are painted with white enamel or light waterproof paint and divisions are calibrated on them with black paint, sufficiently clearly so that the diver can distinguish them well under water. The marks are spaced 1 cm apart.

The sounding rods of the conventional measuring type serve for determining the ship's draft. Divisions are marked on the sounding rods at intervals of 1 decimeter. The last meter has a division /204 value of 1 cm. Use is made of sounding rods of four component aluminum pipes with a total length up to 8 m. Each link is connected with another spring lock, while the lower one has a supporting clip.

The channels are utilized for determining the longitudinal bending (sag, deflection) of the ship's hull.

### Measurements of the Ordinates of Hull's Configurations (Outlines)

To prepare for taking the measurements, we draw up a sketch of the cells' location (spaces between double bottoms) in respect to the ship's length and width. Then, in accordance with the sketch, the marking is transferred to the ship's outer sides. Using a tape measure, the distances are measured between the bow and stern with small weights and in the places of installing the cells, as well as between the cell's axes. The boundaries of the cells (Fig. 131) are then marked.

The location of the cells along the ship hull is chosen so that they would occur in the watertight bulkheads or in the side transverses. The ship's contours influence the choice of the cells' location. The cells' boundaries should be so chosen that their curved (molded) parts would not be too high. The marking on the sides is done with black paint in two places: at the effective waterline, on the bulwark or the sheerstrake.

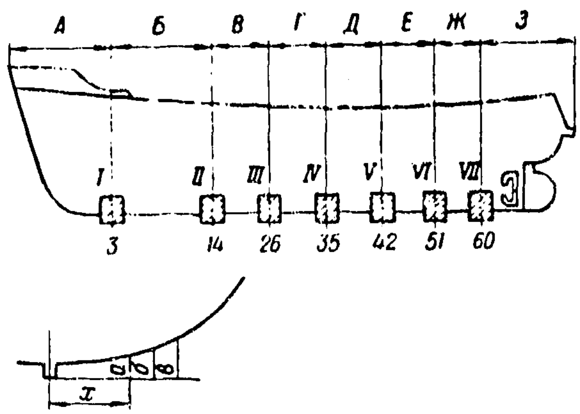


Fig. 131. Marking of Ship Sides for Measurements of the Ordinates: 3, 14, 26, 35, 42, 51 and 60 -- places for installing the waterproof bulkheads or the side transverses; I - VII --places for installing the cells; A - measurement from bow weight to axis of cell I; B, C, D, E, F and G = distances between cells' axes; H = distance from stern weight to axis of cell VII; a, b, c, - ordinates; x = = distance from DP to the first ordinate (to the interior section of the cells).

At the places of measurement, the diver cleans the sides and the bottom of marine fouling and mollusks. The underkeel beam, suspended by eyebolts and having rods nailed to it, is lowered on ropes. The diver aligns the DP mark on the underkeel beam with the ship's DP and sets it in a horizontal position. If the ship has a flat keel, the DP is found by dividing its width in half.

The underkeel beam's horizontal position is checked by measuring with the rule the beam's distance from the outer sheathing at an equal distance from the DP. Having added up the figures obtained and dividing them in half, the diver issues the order to pay out or to haul in the cable on the right or left side.

After the beam has occupied a horizontal position, the supporting ropes are anchored and the diver measures the ordinates. The measuring rule is used from over the side. If the measurement of the ordinates is made on the right side, the rule is laid against the rod from the right-hand side, while during the measurements of the port ordinates, the rule is laid against the rod from the left-hand side (Fig. 132).

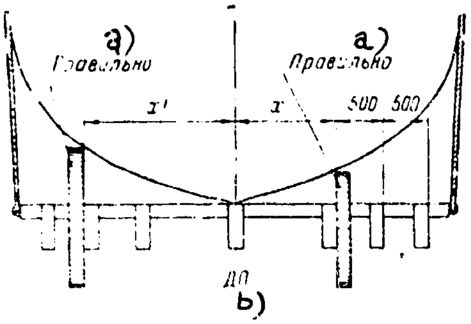


Fig. 132. Measurements of Ordinates: x- distance from DP to first ordinate; $x^1$- distance to second ordinate, equalling X + 500. Key: a) correctly; and b) DP

Successively placing the rule against the rods and leaning it against the sheathing, the diver makes the calculations in centimeters and reports the findings by telephone to the works superintendent, who records these data in a table. /206

| No. in series | No. of ribs (or bulkheads) and cells | Section of cell | Ordinates a | b | c | Distance x from DP |
|---|---|---|---|---|---|---|
| 1 | 1 cell, frame No. . . . . | Bow | | | | |
| | | Stern | | | | |
| 2 | 2 cell, frame № . . . | | | | | |
| . . . | . . . . . . . . . | | | | | |

In each section, there should be at least three measurements per side. After the plotting of the ordinates in a given section, the underkeel beam is moved to the next place for making the measurements, and the entire cycle is repeated. Thus, by means of a sequential displacement along the hull of the ship, we obtain the ordinates in all of the indicated points of the cells' framing.

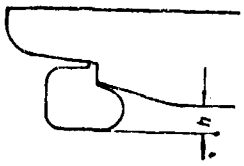

Fig. 133. Position of Rudder Fin Below Base Line.

In order to avoid repetitions in the operations of the alignment and horizontal positioning of the underkeel beam, in each section marks are drawn or attached on the ropes at the level of the upper deck's forming angle. If in proportion to the advancement of the underkeel beam from the stern to the bow, the draft of the ship varies, the presence of marks simplifies greatly the placement of the beam in a horizontal position, since in this instance, the beam's position can be judged according to the difference in the height of the mark's location on the ropes.

In the event that the propeller screw or rudder fin is located below the base line (Fig. 133), this is taken into account in the measurements. The mechanical addition of the draft h to the ordinates' measurements is permitted only if the vessel is standing on an even keel. Therefore we initially establish the vessel's trim difference, then the draft amidships and under the rudder fin or the propeller screws, and only then do we compute the actual draft, with allowance for the trim difference correction. /207

This work is performed in the following manner. The underkeel beam (with a length 1 meter greater than the ship's width) is brought under the middle and is placed in a horizontal position. Using a sound gage, we then measure the ship's draft amidships, i.e. we measure the distance from the underkeel beam's upper edge to the effective waterline. Measurement of the draft is accomplished from both sides; the results are combined and divided in half.

The underkeel beam is then introduced under the rudder fin, levelled with the sounding gage; measurements are taken and the draft is determined. From the data derived, we subtract the amount of the draft amidships; from this result, we subtract (when there is trim difference at the stern) or add (in case of trim difference at the bow) the value of the trim difference. The trim difference is found with the formula:

$$a = C \sin \alpha,$$

where a - the value of the trim difference in linear units; C = distance from amidships to the stern (or bow) weight; and $\alpha$ = angle based on readings from a trim difference gage.

In this manner, the final result will comprise the value h of the vessel's draft, which should be added to the ordinates plotted while the ship is afloat, in the compilation of the dock drawing.

Measuring the Deflection (Sag) of the Ship's Hull. In case the ship keel has an elevation above the base line, i.e. does not coincide with it and has a sag (camber), we should make the appropriate corrections to the plotted ordinates. For measuring the sag, channels are welded to the bow and stern ends of the ship along the diametral plane (DP). The channel's length should be chosen from calculating its draft below the base line by not less than 400 mm.

Having established the ship's draft at the middle, marks are made on the channels corresponding to the waterline and to the base line; then, in previously drilled holes 6-8 mm in diameter (below the base line by about 300 mm), a cable line 0.5 mm in diameter is extended between the channels. One end of the line is attached to the channel while the other is run through the hole in the second channel, and a weight is hung on it to create tension.

Marks are made on the hanger cable corresponding to the cell walls, after which (using a measuring rule) we measure the ordinates, i.e. the distances between the hanger and the ship's keel. The measurement data are reported by the diver by telephone to the works superintendent and are also logged in a table. The measurements are conducted only in the places marked on the hanger and in the places where the transverse ordinates were plotted. (Fig. 134, a).

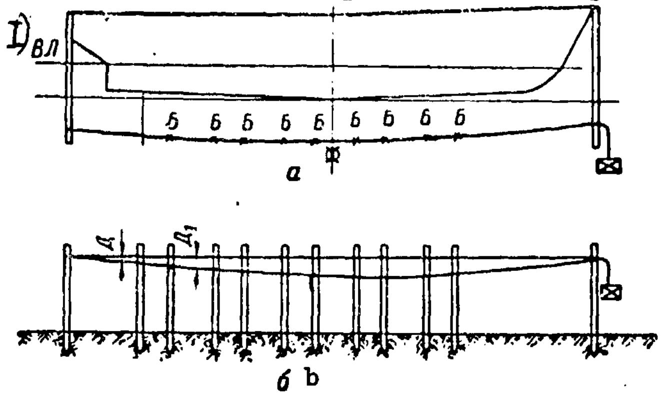


Fig. 134. Determining the Sag (Camber) of a Ship's Hull (Plotting of Longitudinal Ordinates): a- marks for plotting of ordinates; b- measurement of cable's sagging; Б- marks on hanger; Д-- $Д_1$... etc.--amounts of hanger's sagging. Key: D) waterline.

After this, the hanger cable is removed and pulled upward. For the further work, we select a smooth area, level if possible. In this area, we drive two pillars into the bottom, separated by a distance equalling that between the channels. Then, in accordance with the marks on the hanger, the supports are driven in between the pillars. In reference to the water level, the base line is drawn on the pillars and supports. After this, a line is run similarly to the way this was done under water (Fig. 134, b). The suspended hanger will yield the natural sag, which is measured relative to the markers of the base line on the supports.

In this manner, we determine the correction (for the wire's sag) to the longitudinal ordinates taken by the diver. The true value of the ship keel's elevation relative to the base line is determined /209 by subtracting the values for the ordinates of the wire's sagging from the pertinent values of the longitudinal ordinates.

The accuracy of plotting the ordinates will vary within the limits of 20-30 mm from the true dimensions; this is quite adequate for the framing of the cells and for placing the ship in dock. It is advantageous that during the drydocking of the ship, the docking operation be supported by the divers who have measured the ordinates of its hull outlines while the ship was afloat.

### Section 59. Supporting the Docking Operations

The placement of ships in dock is a very responsible operation. In addition to equalizing the listing and the trim difference and positioning the ship precisely according to the weights, of great significance is its moment of equilibrium on the keel blocks and cells. Inaccuracy in the height of an error in the curvature of the molded surface of the assembled cell (space between the double bottom) can lead to damage of the ship's hull.

Therefore the operations involving the docking maneuvers are supported by the divers. They see to it that during the placement of the ship, the dock framing would not be damaged by the projecting parts of the exterior equipment on the ship; they also monitor the balancing of the ship on the keel blocks and cells, and assure the coincidence of the axial line of the dock's keel track with the ship's diametral plane (DP). In case of the detection of a displacement of the ship's keel relative to the keel block's center line, or to the listing or trim difference, disruptions of individual cells, the collapse of beams (blocks) on the keel blocks and other discrepancies, the diver gives an immediate telephonic report to the dockmaster at the surface.

The dockmaster halts the pumping out of the dock (or stops the emersion of the floating dock) and adopts measures for eliminating the shortcomings which have been revealed. In the event that in isolated places, the molded part of the cells does not reach as far as the sheathing (in the limits of 20-40 mm), the diver inserts wooden blocks and wedges, or chops off the projecting parts of the beams with an ax. When necessary, the ship is removed from the dock and the dock framing is repaired.

As soon as the ship rests on the keel blocks and cells, and the diver is convinced that nothing is interfering with its placement, he comes to the surface without waiting for the drying of the dock's building slip (berth). During the tandem placement of ships /210 in dock, the divers monitor the balancing of each ship on the cells and eliminate the deficiencies found, reporting them to the surface.

During the removal of the ship from the dock, the diver supporting the docking operation sees to it that the beams (bearers) of the cells or of the keel blocks would not catch on the hull, and that the dock framing would not be damaged. In case of detecting the catching of beams on the hull or the finding of other difficulties, the docking operation is halted and the diver frees the ship of extraneous objects. The diver comes to the surface only when the ship is removed from the dock.

## CHAPTER 11

## UNDERWATER CLEANING AND PAINTING

### Section 60. Cleaning of Surfaces Under Water

To a considerable extent, the quality of underwater painting depends on the preparation of the surface, primarily on the quality of the cleaning. Therefore we should devote special attention to the questions involved in cleaning. Cleaning the surfaces (removal of marine fouling, dirt, rust, oil, old accumulated paint) under water is performed in the same way as in the dock. In this regard, we should take into account the considerable laboriousness of these tasks, the difficulty of technical inspection, and the poor visibility under water attributable to the turbidity rising during the cleaning process and floating around the work site.

The methods of cleaning under water are fairly diversified:

--cleaning with the aid of mechanical devices;

--manual cleaning with the aid of scrapers, brushes, wire brushes (flat and end-type); for cleaning a wooden hull, we use brushes made of seaweed or of rice roots;

--removal of old paint and rust with the aid of blunt hammers or chisels; and the burning off of the old paint and rust on the metal hulls of ships with the aid of a flame from gas (at slight depth of the object being cleaned) and gas-oxygen burners; usually, the burning-off is accompanied by a subsequent mechanical cleaning of scale and burnt-off paint from the surface.

The flame-type cleaning of the hull is used in the cases when mechanical cleaning proves inadequate. For the flame-type cleaning when the depth of the object being cleaned is up to 3 meters, we use the multi-flame burners, the so-called "combs". /212
In the utilization of gas-fed cutters for burning off the old

paint, it is necessary to cut off the supply of cutting oxygen or to close the cutting oxygen valve in the cutter head.

During the fire-type treatment of the surface, the burner must never be held for long in one place, otherwise burning-through would occur. Nor do we recommend holding the cutter head too close to the surface. The diver should see to it that he burns (turns red) only the scale and old paint.

The cleaning of the metal surfaces is conducted if possible until the surface has a metallic luster; one must not leave traces of dirt, grease, scale or loose paint, while during the cleaning of wooden surfaces, one must avoid leaving traces of algae or shells.

In spite of the generally increased difficulty, the cleaning under water can be accomplished more easily, because the shells and rust or paint (being wet) can be separated from the hull more easily than at the surface. The cleaning should be performed only in a clean basin not contaminated with petroleum products.

An excessively long time delay should not occur between the completion of the cleaning and the beginning of the object's painting, since the surface would again begin to become rusty.

The most popular method of cleaning, in case of the underwater conditions, is mechanical cleaning with the use of wire brushes, with mechanical impact-centrifugal devices of special design and with air hammers. The use of the other types of mechanical cleaning of a ship hull, i.e. sand-blast and shot-blasting, is not feasible when underwater conditions are involved.

The triple air hammer is designed to remove rust, scale and old paint (Fig. 135). The presence of 3 heads increases its output considerably. As a whole, as compared with manual cleaning of a surface, its processing with the triple air hammer increases the productivity by 5-8 times, and greatly facilitates the operator's work. The technical specifications of the hammer are listed in Appendix 25.

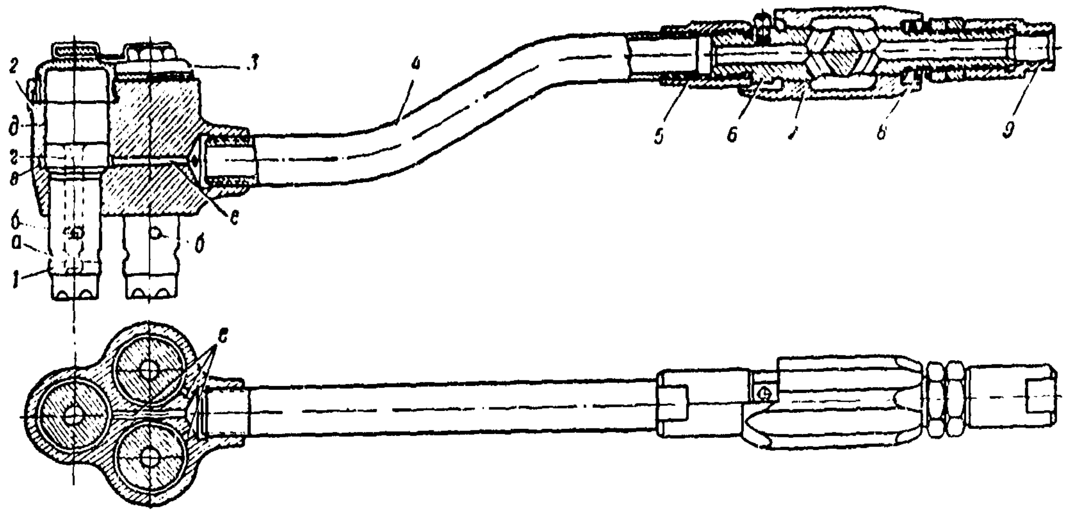

Fig. 135. Triple-Head Air Hammer: a, b, d, f--channels; c - annular chamber; e - upper chamber; 1 - faces; 2 - frame; 3 - cover; 4 - pipe; 5 - coupling; 6 - bypass pawl; 7 - bypass coupling (lever); 8 - spring; and 9 - sleeve.

The triple-head air hammer consists of frame 2 and of 3 faces, 1, a pipe 4, and a bypass coupling (lever) 7 serving for controlling the supply of compressed air to the hammer.

Frame 2 has 3 channels along which compressed air is fed to the cavity in which the hammer faces (strikers) move. Strikers 1 have radial ducts a and b, and a longitudinal central channel c, serving for the passage of compressed air.

To assure uniform wear of the working surface during the work, strikers 1 are given a slight rotary motion, which is provided by shifting radial ducts a and b.

Starting the hammer is achieved with the aid of the bypass coupling 7 (starting lever), which is turned by 1/2 - 3/4 of a revolution. At this time, the slots in coupling 7 line up with the channels in the bypass pawl 6, and air passes through pipe 4 to frame 2 of the head.

Along the 3 channels, f, in frame 2, compressed air enters the annular chambers c, formed from the annular slots in frame 2 and the body of the strikers, 1. Under the effect of the compressed air fed to the annular steps, strikers 1 move upward, forcing the air from chamber e through the central chamber d connecting with the ambient atmosphere (medium) by the radial channels a and b.

The rising of strikers 1 will occur until the radial channels f, i.e. they reach chambers c. The air will advance further through the central chamber d to chamber e, creating pressure and causing the downward motion of the striker, once again up to the time of connection of the radial ducts a and b with the surrounding atmosphere. Thus, owing to the presence of the bypass channels, strikers 1 act as unique slide valves.

Strikers 1 will move downward by inertia until their kinetic force has been spent; in this connection, they strike the surface subject to cleaning.

As soon as the pressure in chamber e is balanced with the ambient pressure, the cycle is repeated, i.e. the compressed air in the annular chamber c once again begins to press against the projections of the strikers and to move them upward, etc. In this manner, during the work process the strikers accomplish /215 a reciprocating motion.

The design is fairly simple and usually no particular difficulties develop in the work. One need only take care of the hammer carefully and lubricate it at least twice weekly, since otherwise corrosion can originate. As the strikers become worn, they should be replaced.

In working with the triple-face hammer, one should have in mind that for slight thicknesses it is inapplicable since there is a danger of damaging the sheathing.

Clustered Air Hammer. For rough surfaces, for working in difficultly accessible and inconvenient points, use is made of the clustered hammer (Fig. 136). It is used for knocking off the old paint, rust, scale and so forth.

The clustered hammer consists of a frame 1, striker 2, a tapered bushing 5, and of an insert 3. The head (frame 1 and striker 2) is equipped with a cluster of rods 6, inserted into grid 4 and of a lever, consisting of the bypass coupling 11, with bypass pawl 10 inserted in it. Frame 1 is equipped with the threaded cap 7, guarding against the accidental loosening of the annular spring-type plug fastened with pin 8.

For imparting direction to the rod cluster, use is made of bushing 5, while grid 4 protects rods 6 from falling out. Similarly to the faces of the triple hammer, striker 2 has central and radial channels permitting the passage of compressed air.

When it is necessary to lengthen the lever to the welded-on support on frame 1, an extension pipe is screwed onto the thread; in this way, we are able to derive a modification of the cluster-type hammer, similar to the triple-head one (see Fig. 135). In this case, the hammer becomes convenient for working in narrow confines and in other places where access is difficult.

The hammer is started by turning the bypass coupling 11; at this time, the coupling slots line up with the ducts in the bypass pawl 10, while spring 12 holds the coupling in the prescribed position.

The compressed air arrives at frame 1 in chamber b, formed by the frame cylinder and by the body of striker 2. The compressed air presses on the annular lug of striker 2 and forces strikers 2 to move upward. The air occurring in the upper chamber a is forced out of it and, passing along central channel c and the radial channels d and f, it connects through the lower chamber g and the outlet holes e with the ambient atmosphere (in our case, with the surrounding medium). The motion of striker 2 is /216 reciprocating and is achieved under the effect of the compressed air which passes from chamber b into chamber (duct) a through ducts c, d and f just as in the triple hammer. At the end of the downward motion, striker 2 inflicts a blow through the bushing 3 against the cluster of rods 6, which in turns strikes against /217 the surface which is being cleaned.

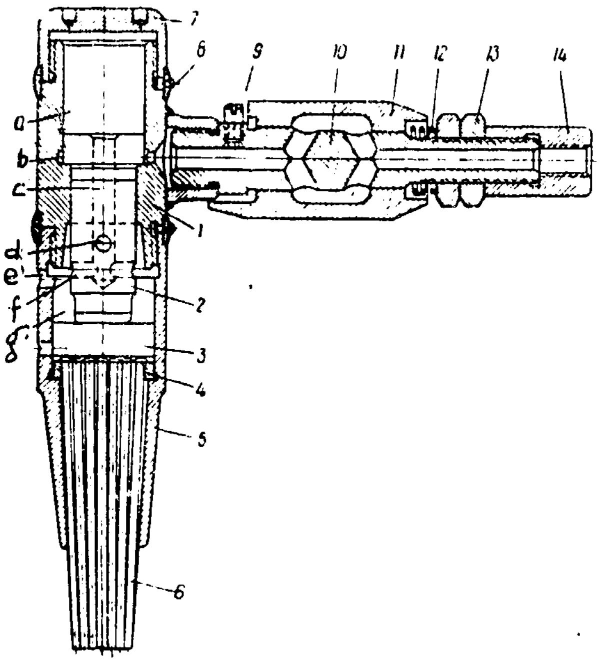


Fig. 136. Cluster-Type of Pneumatic Hammer: a - upper chamber; b - annular duct; c,d, and f - channels; g - lower chamber; e - outlet holes; 1 - frame; 2 - striker (face); 3 - bushing; 4 - screen; 5 - sleeve; 6 - cluster of rods; 7 - cover; 8 - plug; 9 - pressure screw; 10 - bypass pawl; 11 - bypass coupling; 12 - spring; 13 - nut; and 14 - connecting sleeve.

The technical specifications of the cluster-type hammer are listed in Appendix 25. The rules for maintenance during operation are the same as during the work with the triple hammer.

Among the disadvantages of the cluster type of hammer, we should include low productivity. To avoid corrosion of the striker's track, the hammer should be lubricated often; also, each time following the work under water, it is necessary to remove sleeve 5 and to wipe the rod and its internal cavity dry with a clean cloth.

Impact-centrifugal Machine for Cleaning. In addition to the air-driven tool, for cleaning the hulls of ships of old paint and rust, use is made of other devices. The small percussion-centrifugal machines driven by an electric motor have gained fairly wide popularity. A variant of such a machine equipped with wire brushes instead of strikers is shown in Fig. 137.

An advantage of these small machines is the fact that a sliding blow is made against the surface which is being cleaned, and thereby there is a reduced danger of damaging the surface during cleaning. At the same time, for the intensively hardened paint, the use of such machines is usually of insufficient effectiveness, and it is necessary to resort to pneumatic hammers.

The percussion-centrifugal machine is driven by an electric motor which is located at the surface. The electric motor turns the flexible shaft 1; the latter in turn drives spindle 9 on which a ring is mounted containing the strikers or, as in the given case, with the wire brushes 11, hanging freely on the working axes 10.

At the turning of spindle 9, the wire brushes 11 deflect toward the outside, and at contact with the surface, they inflict a slanting sliding blow on it. The deflection of brushes 11 occurs owing to the centrifugal forces developing during the rotation of spindle 9.

During the operation with the percussion-centrifugal machines, it is necessary to insulate the flexible shaft 1 from the admission of moisture. For this purpose, it is mounted in a rubber hose. After the activity under water, the machine must be cleaned carefully until it is dry, first having been rinsed in clean fresh water. For better sealing, we recommend the installation of gaskets in all points where the bearings come in contact with the water.

Covering 6, extremely necessary during work while in dock, can be removed if during the operation it will create much resistance; however, this problem should be solved by the operator himself in each actual case.

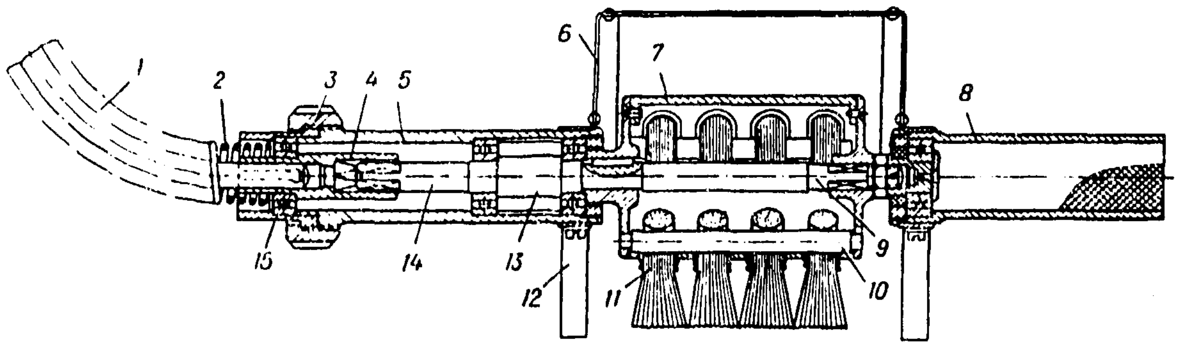


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Fig. 137. Percussion-Centrifugal Machine for Removing Rust and Paint (model equipped with wire brushes): 1 - flexible shaft; 2 - spiral spring; 3 - union nut; 4 - collet; 5 - lever; 6 - protective covering; 7 - ring (clip); 8 - lever; 9 - spindle; 10 - working axis; 11 - wire brushes; 12 - support; 13 - sleeve; 14 - tail piece (shank); and 15 - ball bearing.

Among the shortcomings of these devices, we should include the relatively quick crumpling of the brushes and the twisting of the flexible shaft, which prevents the performance of the work at a great distance from the driving motor.

Besides the equipment described, for the cleaning we can also use a paint machine and other devices, in which in place of the working disk we place an end-type wire brush 190 mm in diameter. For a description of the paint machine, see below.

Section 61. **Underwater Painting of Surfaces**

Painting occupies the basic role among the various means for available combatting the corrosion of metals. Paint applied to a surface creates a compact and stable film which stops the entrance of moisture and protects the object from corrosion. Special rules establish the sequence, periods and types of paints used for ships. Painting the exterior sheathing of ships (including the submerged side) is conducted during the scheduled moorings of the ship. In individual sectors of the sheathing in the ship hull's submerged part, it is sometimes necessary to refurbish the paint film without waiting for a scheduled drydocking, since this is conducted only once per year.

Corrosion of the ship hull develops most intensively in the region of the variable waterline, the bow surf and the stern overhang, at the points of the varying effect of air and moisture on the sheathing; in addition, there occurs the purely mechanical attrition of the coating film during the continual washing of these sectors by water.

If we overlook the inconvenient and onerous task (for the ship's crew) of painting the area of the variable waterline during careening, and the stern overhang and stem with establishment of trim difference, in the ship repair practice there is essentially no method permitting us to restore the paint film on the hull's submerged part without drydocking the ship.

All the familiar techniques for painting the surfaces in air /22C
are unsuitable for painting on a wet surface. Most of the researchers have suggested solving the problem of underwater painting by the development of special paints and the utilization of the existing methods for their application. However, owing to the high cost and the lack of adequate conditions for the manufacture of these paints, they have not yet been put on a production footing.

We can also solve this problem by seeking or developing techniques for applying (during underwater conditions) the paints now being produced by industry. The main difficulty is the forcing back of the microfilm of moisture from the surface. The centrifugal painting method which has been developed provides the application onto a prepared (cleaned) metal surface, of a stable and compact film under submerged conditions or onto a wet surface in the dock.

The centrifugal painting under water, suggested by the author, according to experience can be utilized for the painting of wet surfaces, during drizzling rain and during condensation conditions.

The gist of the centrifugal painting technique consists in the uniform distribution and rubbing of paint over the surface with a spongy working disk turned by a pneumatic motor. The paint is fed under pressure through a central orifice in the disk. From the effect of the centrifugal forces, during the rotation of the working disk, the paint is spread over its surface and is transferred (rubbed) onto the surface which is being painted. The paint is applied with a mechanical force which favors an improved crowding out of the moisture and hence an improved adhesion of it with the surface.

According to the research conducted by Academician P.A. Rebinder, the painting of a hard moist surface is based on the phenomena of selective wetting. Certain liquids run easily over the surface of a working body or over the surface of a nonmixing liquid, and form a thin film; other liquids, on the other hand, roll off, retaining the shape of a drop, and do not wet the surface.

The ability of a liquid to wet or not to wet a surface depends on the energy relationships at the interfaces of three phases (solid-water-paint) (during underwater painting) or solid-air-paint (during painting on the surface) and on the relationship between the forces of adhesion with the surface which is being painted, and the surface tension of the liquid (cohesion). /221

The greater the adhesion and the less the cohesion, the better the liquid wets the solid. Therefore a liquid with a low surface tension will flow over the surface of the liquids possessing a high surface tension, forcing them from the surface of the solid, wetting the latter effectively.

The coal lacquer and the ethynol paints which are utilized for underwater painting have a surface tension within the limits of 17-25 erg/cm$^2$, while for water at 20$^\circ$C, the surface tension equals 72-75 ergs/cm$^2$. Water is not as efficient in wetting a solid as hydrocarbons, and this creates a basis for removing the microfilm of water from the surface which is being painted. Painting in fresh water or on a wet surface is accomplishable without any limitations, but painting in saline sea water is possible only under the condition that the salinity does not exceed 2%. With an increase in the water's salinity, the paint ceases to wet the surface.

In addition to observing the wetting conditions, to provide high quality of the painting, it is necessary to spread the paint over the surface of the object; when underwater conditions are involved, this cannot be done manually with a brush. Thus, for assuring a satisfactory quality of painting the surfaces under water, it is necessary to have a mechanical drive developing a rotation of the working disk with a speed of approximately 250 rpm.

The centrifugal procedure of underwater painting has a number of positive features; as the practice has shown, in their strength and plasticity the films are equal to those obtained by the brush method on a dry surface. The viscosity of the paints used is higher and consequently the depth of the layer applied is greater; this permits the obtainment of a controlled thickness of coating in a smaller number of layers (e.g. 3 layers instead of 4).

The expenditure of materials during the centrifugal method of painting corresponds roughly to the expenditures involved in the /222
brush method of applying the coats. The utilization (expenditure) of sponge for the working disks depends on the condition of the surface which is being painted. Specifically, during painting with ethynol lacquer on a wet surface, with one rubber sponge-type disk, we painted 150-160 $m^2$ of metallic surface.

During the painting with coal-tar lacquer, according to the preliminary data the productivity of the centrifugal method comprises 27 $m^2$/hr, while with ethynol paints, it amounts to 16-20 $m^2$/hr. In proportion to the improvement in the equipment and the acquisition of good work habits, the output achieved during underwater painting will increase.

The centrifugal painting method can be recommended during selective painting under water, i.e. in painting the repaired sections of a ship, individual places where the paint film has been damaged, parts of the bottom equipment which are being replaced, patches, etc.

## Section 62. Equipment for Centrifugal Painting Under Water

In their design features, the existing painting machines and mechanical brushes proved unsuited for painting under water. The equipment developed for centrifugal painting under water is still far from perfect but it does provide the application of a high-quality coating during underwater conditions with a small volume of work.

The apparatus for centrifugal painting (Figs. 138, 139) is comprised of the following units: a small painting machine 1, a small paint-pumping tank 2, a water-oil separator 3; in case of working in dock during the painting of a wet surface, use is also made of a balance beam for supporting and balancing the painting machine (Fig. 140).

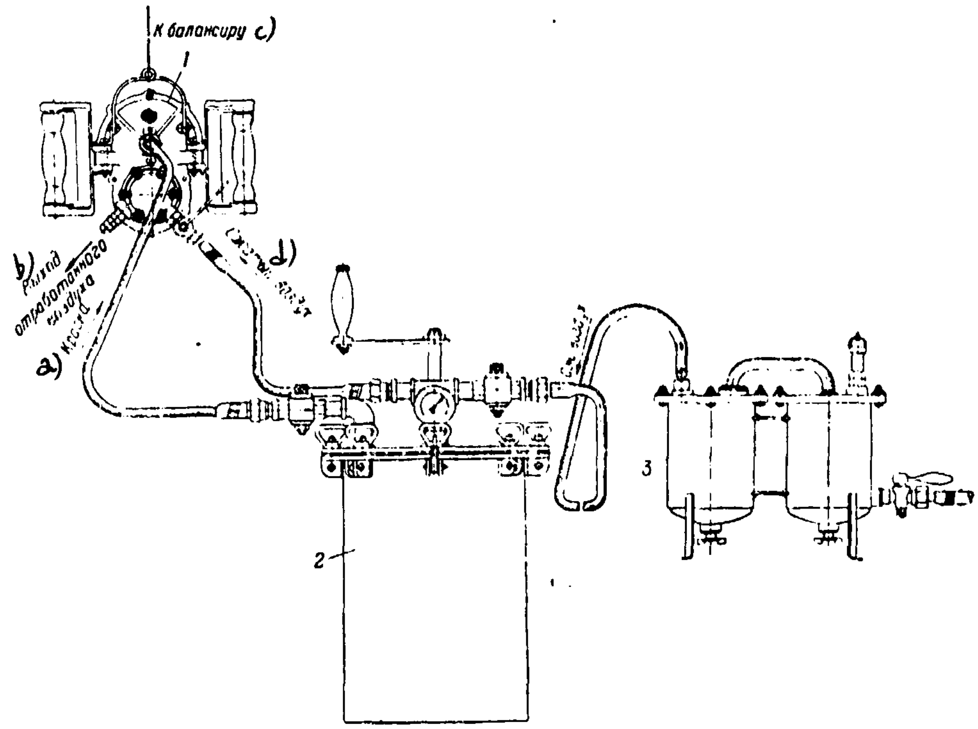


Fig. 138. Apparatus for Centrifugal Painting Under Water: 1 - pneumatic painting machine; 2 - paint-pumping tank; and 3 - water-oil separator. Key: a) paint; b) outlet of spent air; c) to balance beam; and d) compressed air.

For concentrating the lacquer to the viscosity required in the application by the centrifugal method, we resort to an electric heater operating on the principle of a water or sand bath. /224

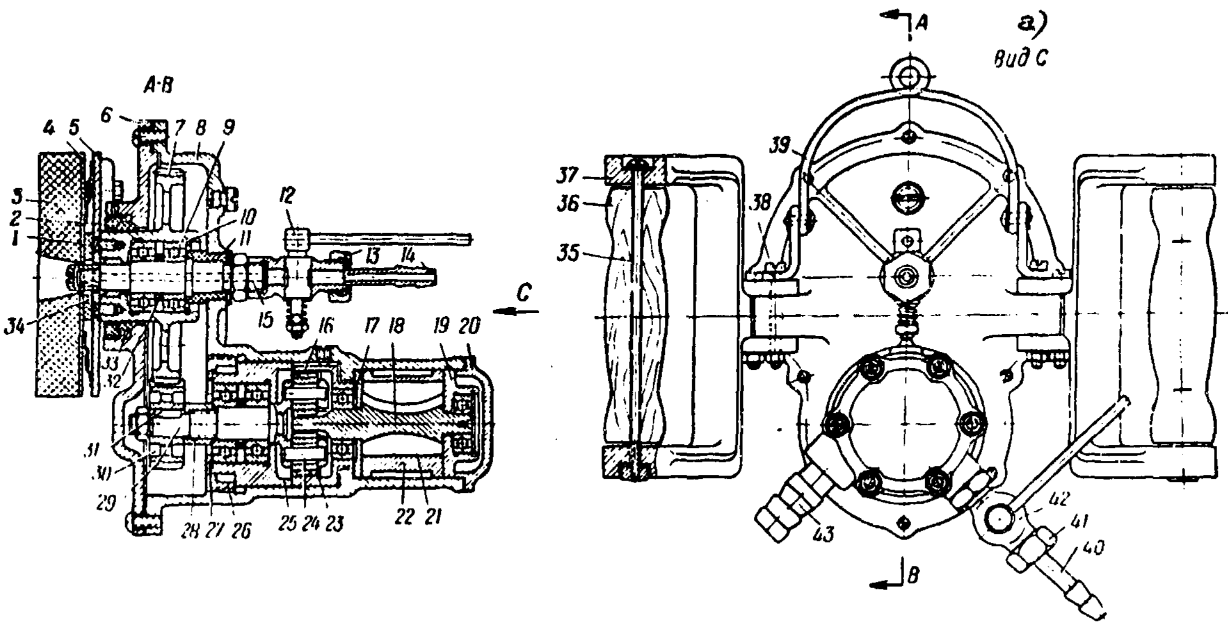


Fig. 139. Pneumatic Rotor-Type Machine for Painting with the Centrifugal Method: 1 - intermediate ring; 2 - stuffing box nut; 3 - sponge-type rubber disk; 4 - removable working disk with slides; 5 - main disk ( of faceplate) with slides; 6 - frame cover; 7 - driven gear; 8 - frame; 9 - ball bearing; 10 - spring-type ring; 11 - frame bushing; 12 - inlet valve for paint; 13 - union nut; 14 - nipple; 15 - spindle; 16 - crown gear; 17 - lower cover of stator; 18 - rotor; 19 - upper cover of stator; 20 - frame cover; 21 - blade of small turbine; 22 - stator; 23 - intermediate gear; 24 - needle-type bearing; 25 - end-type bushing; 26 - threaded ring; 27 - support key; 28 - nut to central shaft; 29 - central shaft; 30 - driving gear 31 - prismatic key; 32 - intermediate ring; 33 - stuffing box; 34 - bushing; 35 - screw; 36, 37 - frame levers; 38 - support loop; 39 - suspension; 40 - nipple for air hose; 41 - union nut; 42 - plug-type valve for feeding air; and 43 - nipple for diversion of processed (spent) air. Key: a) view C.

The technical specifications of the equipment for centrifugal painting are presented in Appendix 26. In addition, the equipment incorporates hoses for conveying the paint and air, plus assmebly tools, including special wrenches to the painting machine, and a viscosimeter (VZ-4 funnel) for determining the lacquer's viscosity prior to pouring into the tank. The painting is done in a water basin free of the residues from petroleum products.

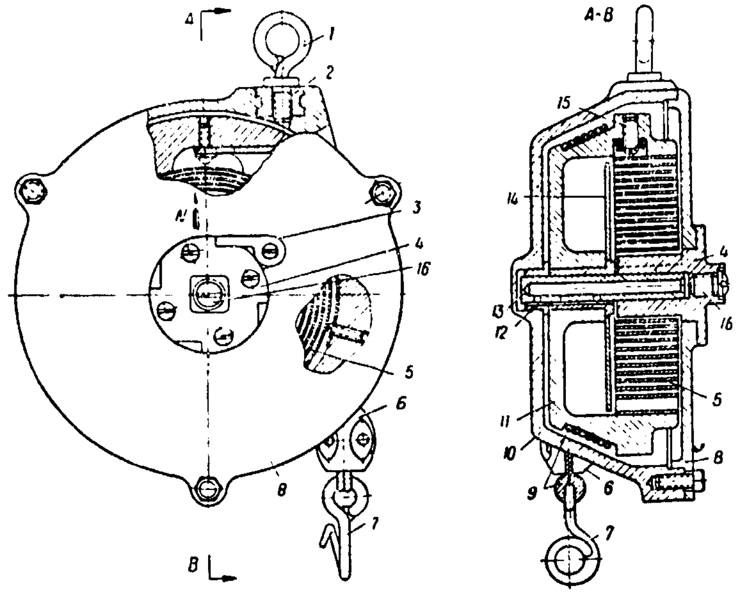

Fig. 140. B lance Beam for Supporting the Painting Machine: 1. --eyebolt; 2 - bushing; 3 - support; 4 - ratchet; 5 - spring; 6 - ring (clip); 7 - hook; 8 - cover; 9 - small cable; 10 - frame (housing); 11 - drum; 12 - bushing; 13 - axis; 14 - washer; 15 - screw; and 16 - plug.

For underwater painting, the paint of the required viscosity is poured into the tank and compressed air is connected from a compressor; calcined granulated coke 20X20X30 mm in size is poured into the water-oil separator. After testing the operation of the arrangement, the machine is lowered on a rope to the diver.

The working element in the machine is the sponge-type rubber disk 3 (Fig. 139), which is glued to metal disk 4, connected by slides with faceplate 5. This permits an easy replacement of the /226
worn-out sponge disks.

The diver opens the valve 42 for admitting the compressed air to the machine and then starts the machine; he then opens valve 12 delivering the paint. The supply of the paint and the turning of the face plate are regulated in such a way that the paint would uniformly cover the spongy disk without spattering. After this, the machine is pressed by spongy disk 3 against the surface, and in proportion to the application and levelling of the paint, the machine is moved along the surface being painted in such a way that there would not be any breaks in the film. Particular care is taken in painting the riveted and welded joints, cavities and other irregularities. At completion of the painting, the flow of paint is cut off, then the air supply, and the machine is shut down.

In order that the spent air would not create bubbling in the direct vicinity of the surface being painted, onto the outlet nipple 43, we attach a piece of hose 1.5-2 m long, preferably with a float. After the completion of the work, the machine is pulled to the surface and the valves in the pressure tank are closed.

After being raised to the surface, the machine is disconnected from the hoses, the spongy disk is removed, and the machine is washed carefully with kerosene or gas, and wiped dry. The removable spongy disk is simply wiped dry. Kerosene or gasoline should not come in contact with the spongy surface, since it damages the rubber. The hoses, particularly the paint hoses, are carefully blown through with air and only then is the equipment disassembled.

During extended storage, the moving parts of the painting machine are lubricated liberally with spindle oil, while on the outside they are coated with technical petrolatum; the machine is wrapped in waterproof paper and placed in the prescribed storage facilities.

The painting machine which is being used is heavy and this quickly fatigues the worker. There are lighter-weight rotor-type machines for painting on the surface which should be adapted for centrifugal painting under water. In place of the sponge rubber disk, it is feasible to use paralon or some other spongy plastic which is resistant to petroleum products, having a resilience equal to that of sponge rubber.

## Section 63. Paints Suitable for Underwater Application

Of the standardized paints, only the ethynol paints and coal-tar lacquer are suitable for application under water or on a wet surface. The adhesive and latex paints are unfit for underwater application. The paints ground in a paint vehicle, enamel and also the perchlorovinyl dye type of paint proved unstable, although they can be applied easily in underwater conditions. /227

Coal-tar lacquer is produced in accordance with GOST (State Standards) 1709-60, with an original viscosity of 2 min--2 min 30 sec (at 20°C). For centrifugal painting, only grade A lacquer is suitable, in which its viscosity is reduced to 8--14 min (at $t = 20°C$). The time of the lacquer's drying under water will range from 24-32 hours.

Coal-tar lacquer is a dark liquid, formed as a by-product during the coking of coal and consists of asphalt (40%), pitch (25%), of heavy oils (30%), and of other admixtures (5%).

**Ethynol Paints.** At the present time, many new paints have been developed which are based on ethynol lacquer. These paints are those plasticized with chloroparaffin, brand DP, the ethynol paints, brand EKZHS and EKSS (the former ETSOL paints), the modified ethynol paints, brand EKKL(combinations of ethynol and coal-tar lacquer) and ELM, bituminized paints of brand EKBT, the epoxyd-ethynol lacquers, brand EE, and the EPK brand of ethynol-perchlorovinyl paints.

From this entire assortment of ethynol paints, only the paints of brand EKZHS, EKSS and EKKL have passed a practical test. However, there is a basis for assuming that other modified paints on an ethynol base will show excellent results, especially the types EE and EKBT paints.

Less dependable for underwater application are the brand ELM paints and the plasticized DP brand of paints, chiefly as a result of their slow drying. The technical specifications and the compositions of the ethynol paints, recommended for application under water and onto a wet surface, are presented in Appendixes 27 and 28 below.

Ethynol, or divinylacetylene, lacquer is a by-product obtained from the production of synthetic rubber and comprises a 40-50% solution of nonvolatile polymers of acetylene in xylene. Ethynol /228 lacquer (varnish) is volatile and unstable; therefore, as a stabilizing agent, we add to it the auto-antioxidant of the AO type, or the antipolymerizer, type AP.

Ethynol lacquer is manufactured in conformity with TS (Technical Specifications) 1267-57 with an initial viscosity of 13 sec. For application when underwater conditions are involved, the ethynol lacquer is subjected to concentration (distillation of the volatile substances) in an electric heater to a viscosity of 2 min 15 sec--2 min 45 sec. A filler, for example iron oxide or red lead, is added to the concentrated lacquer.

During the testing, the ethynol lacquer showed stability and strength of its film on a par with the film applied in drydock to a dry surface. Depending on conditions, under water the ethynol paints dry out in 18-24 hrs. The viscosity of the lacquer or paint is established with the VZ-4 viscosimeter. For this purpose, a sample is taken from the total batch of lacquer comprising about 300 $cm^3$ and is held in air for 20-30 min in order that the lacquer would acquire the temperature of the ambient air.

Having strained the lacquer through a screen with a mesh size of 160 holes/$cm^2$ and having removed the foreign admixtures and films, it (lacquer) is poured into the viscosimeter funnel (Fig. 141). At this time, to prevent the lacquer from flowing out, the funnel's spout is squeezed together with one's fingers. Having filled the funnel to the brim and having prepared a small glass container and a stop watch, one releases the spout and at the same time activates the stopwatch. The time required for the outflow of the filled funnel (the inside volume of which amounts to 100 $cm^3$) is a measure of the liquid's viscosity. The determination of the lacquer's viscosity is repeated at least twice with an accuracy up to 5-10 seconds.

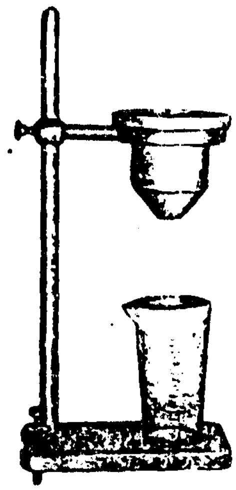

Fig. 141. Viscosimeter - GIPI-4 Funnel (VZ-4).

During the painting of the ship's hull, we usually apply 3-4 layers; moreover, each successive layer is applied after the preceding one has dried completely. The drying time depends on the water temperature, season and area in which the ship is located. /229

In order to differentiate the layers during the painting of the ships according to the systems (ordinarily a 3- or 4-layer application), we add a pigment to the paint, for instance lampblack. Thus, the layers are applied alternately—one layer with pigment, and another without pigment, and so forth. One must never add cement to the paint, since as it sets, it settles onto the walls of the pipelines and hoses, quickly putting the equipment out of operation.

## CHAPTER 12

## TECHNICAL INSPECTION DURING THE UNDERWATER SHIP REPAIR ACTIVITIES

The technical monitoring of the underwater ship repair operations is achieved within the overall system of the organization of the technical supervision at a ship repair enterprise.

Special significance in the conditions of underwater ship repair is acquired by the intermediate monitoring by way of the inspection by one diver of the tasks completed by another diver, for instance the fitting and tack-welding of a patch by a diver-hull repairman is accepted by the diver-welder prior to the welding.

The final inspection consists in determining the quality and scope of the tasks completed prior to presentation of the object for delivery to the purchaser. The director of the USRS (Underwater Ship Repair Stations) or the senior official at the station makes the final checkup on the tasks which have been performed.

### Section 64. Technical Inspection During Underwater Welding and Cutting

Supervision of Underwater Welding. In the preparation of the objects for underwater welding, we conduct a verification of the chamfers taken (the bevel angle of the edges) and of the clearances between the sheets, plus the correctness of placing the tack-welding.

After the welding, we perform an external inspection of the joints and verify their dimensions. For the measurements, use is made of a general-purpose angle template (Fig. 142.). The defects found (undercuts, burned through spots, overflows, deviation of the seam, nonfusions etc.) are cut out and re-welded.

The important joints are checked with radioscopy, by use of /231
radioactive materials directly in the underwater conditions. This method of inspection permits us to detect any internal defects in the welded joints (cracks, nonfusions, slag and gaseous inclusions, etc.) without breaking the joints open.

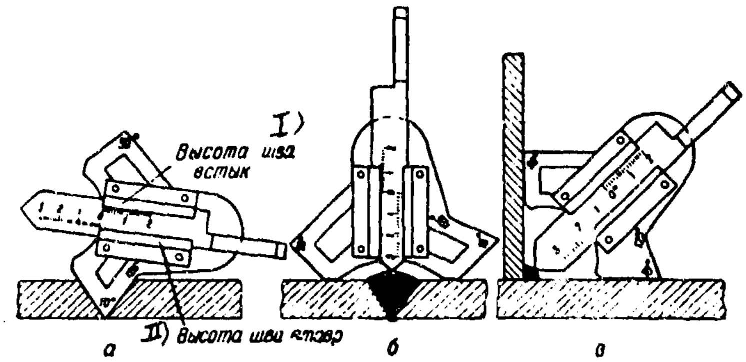


Fig.142. General Purpose Angle Template for Inspecting the Welded Joints: A - checking the preparation of the edges in case of butt-welding; B - measuring the height of a butt-welded seam; and C - measuring the height of a fillet weld in a T-joint. Key: I) Height of Butt-Welded Joint: II) Height of T-joint.

The gist of the method consists in the idea that the gamma-rays of a radioactive substance, passing through the welded joint, act upon a photographic film and based on the photograph thus obtained, we establish the presence of internal defects in the welded seam.

As a radiating device, we apply radioactive cobalt and other materials. The water disperses the gamma rays and therefore the clarity of the image in the photograph taken in water is inferior to the image taken in air. In connection with this, during the underwater gammagraphy, we recommend the use of the so-called "soft" emitters which yield photographs having a sharper contrast.

In Figs. 143 and 144, we have shown the systems for the radioscopy of welded seams with an ampule of radioactive substance. With the aid of gamma-rays, we subject to radioscopy the products made of metal, having a thickness up to 300 mm, wherein we detect defects amounting to 4-5% of the product's thickness. For metal with a thickness of less than 200 mm, the sensitivity is least of all--i.e., 8-9% of the thickness.

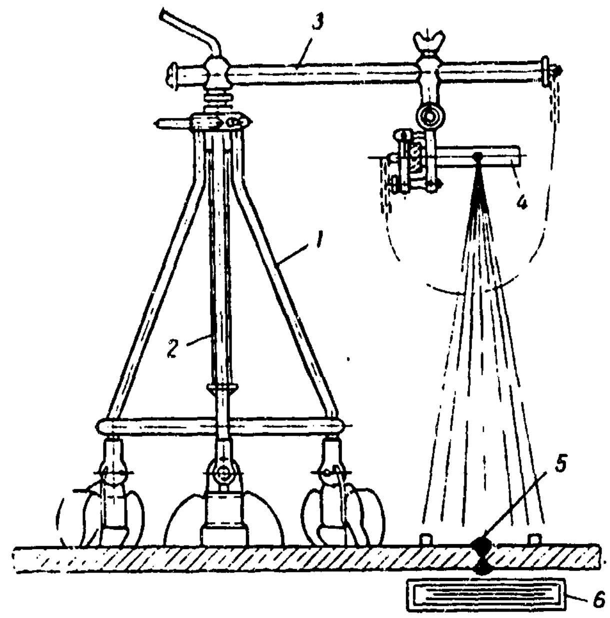


Fig. 143. Diagram Showing the X-Ray Inspection of Welded Joints: 1 - stand containing permanent magnets; 2 - vertical guide; 3 - horizontal guide (track); 4 - can containing an ampule of radioactive substance; 5 - welded seam; 6 - case containing the film.

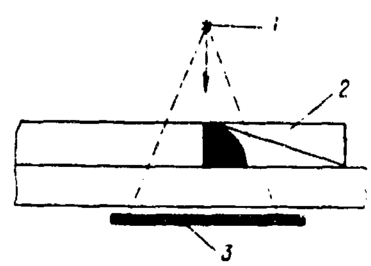


Fig. 144. Diagram Showing the X-Ray Processing of Fillet Welds (of Welded Seams in the Ship Sheathing): 1 - vial containing the radioactive substance; 2 - balancing wedge; and 3 - cassette (film holder).

In the two-sided lap joints, the tightness of the welded joints can be checked with compressed air. For this purpose, the seam is drilled and compressed air is connected; thereupon, the appearance of bubbles will indicate any breaks in the welded seam.

The tightness of the welded seams is checked by pumping the water out of the flooded compartment. The presence of leakage (filtration) indicates the loosenesses of the joints. The defective sections are cut out and are re-welded under balanced pressure, i.e. with a preliminary filling of the compartment with water up to the level of the outside sea water.

The indirect types of welding inspection include a verification of the quality of the electrodes based on a certificate, by the preparation of spot-checking specimens, and also the tests of the diver-welders for releasing important items for welding, with the issuance of permits. If a permit is lacking or has expired, the diver-welder is not allowed to proceed with the responsible tasks.

In the inspection of the underwater cutting, special attention is paid to the provision of a continuous cut. For this purpose, preliminary irradiation is accomplished from the reverse side, and with a diver's knife or an electrode, it (irradiation) is run along the entire cut. The overflows, crosspieces and burrs which have been detected are trimmed off with a chisel.

## Section 65. Technical Inspection During the Assembly and Repair Tasks

During the inspection of the assembly and repair work, a verification is made of the installation dimensions and of the assembly marks, as well as the action of the mechanisms. For instance, the verification of the propeller's seating on the cone of the shaft, the observance of the clearance between the propeller hub and the stern (deadwood) bushing, the verification of the effect of the rudder by setting it from one side to the other with simultaneous observation of the rudder indicator needle, etc., i.e. the same requirements are imposed on the quality of the assembly and repair (fitting) tasks as during the performance of these jobs at the dock.

We also observe the requirements and the standards established for the dock repair for seating, tightening, fitting, scraping etc.

## Section 66. Technical Inspection During Operations on a Ship Hull

The monitoring of the hull repair tasks includes the verification of conformity of the prepared elements (patches, duplicating sheets, framing units)to the dimensions of the restored sections of the ship hull and its configurations, and also of the verification of the tight fit of the joints in the exterior sheathing (planking).

In distinction from repair while in drydock, at sea the verification of the tightness of the outer sheathing is accomplished by pumping the water from the flooded compartment. If the compartment has not been completely flooded, we examine from the inside only the restored section of the hull sheathing.

Monitoring the Tasks on Plotting the Ordinates of Ship Hull Configurations While the Ship Is Afloat. A careful check is made of the correctness of installation (suspension) of the underkeel beam and of the measuring rods.

The monitoring of the concrete work is accomplished according to intermediate operations: first, we check for the cleaning of dirt, rust and grease from the surface to be concreted; then we check on the correctness of installing the reinforcing steel and forms, etc. The quality and composition of the concrete before pouring is verified at the surface.

After the concreting, the main attention is concentrated on the hardening of the concrete and on the increase in its strength.

Inspection of the underwater cleaning of the ship hull is conducted directly prior to the painting and consists verifying the removal of marine fouling, scale, rust,old paint, bulges etc. In this connection special attention is diverted to cleaning the local recesses in the welded and riveted joints. The surface is considered to be ready for painting if during its wiping with a cloth, no rust would show up on it.

Between the completion of the cleaning and the start of the painting, the delay should not exceed 12 hours, since otherwise the surface could become rusty again. Before the painting, the surface of the hull's above-water part should be cleaned again with a cloth.

The monitoring of the painting quality is conducted by a direct inspection of each layer of the painted surface. In this connection, we check to see that each successive layer has been applied only after the preceding one has dried. A low-quality brushing of the paint, the presence of a pattern, cracks or exposures of the metal (unpainted places) are not permitted.

Simultaneously with painting the ship's hull, we paint a control plate which is hung by the object (place) of painting. /235
The paint dries on the control plate and on the object simultaneously and under uniform conditions. The drying of the film and the quality of its application are checked both according to the control plate as well as directly on the object by the methods of imprinting and perforation-type incision.

An attachment (Fig. 145) with a rubber fitting is pressed through gauze against the painted surface. If the surface does not release loosened parts and an imprint of the device does not remain on the film, the paint is considered to be dry. The method of perforation-type incision is used for determining the adhesion of the paint with the metal.

Using a knife, on the control plate at an angle sloped with the surface, we make 4-5 parallel incisions of the paint down to the metal at a distance of 3-4 mm from each other, and the same kind of incisions are made perpendicularly to the first ones. If the adhesion of the coating with the metal is good, the grid (network) turns out to be a uniform, with the remnant of a film. In the case of faulty adhesion, the pattern is disrupted, the edges of the incisions prove to be torn, and the film stands away from the metal.

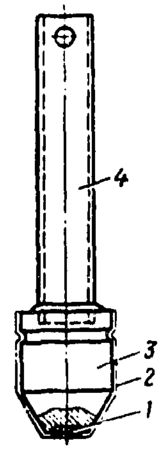


Fig. 145. Device for Determining the Drying of the Paint and Varnish Coatings: 1 - rubber attachment; 2 - gauze; 3 - tip; and 4 - handle.

In this instance, the film is removed and the defective section is repainted. If the checking on the quality of adhesion is conducted directly on the ship hull, the grid-type incision is made in several places. After the checking, the pattern cut with the knife is painted over.

The thickness of the covering layer is checked against the control plate by measuring the dried film with a micrometer. For the various types of coatings, the film's thickness will differ. For a coating film made of Kuzbas lacquer, the layer's thickness must not be less than 60 microns, while the overall thickness with three-layered application is not less than 180 microns. In the ethynol paints, the coating's total thickness must not be less than 130 microns.

## Section 67. Technical Inspection of the Rigging Operations

In the performance of the rigging tasks, we check for the correctness of selection and proper condition of the hoisting equipment, especially their braking units. We verify the proper condition of the cables, the conformity of their dimensions, quality, and also the strength of the knots which are being tied and the correctness of the rigging.

The requirements imposed on the technical inspection of the rigging operations are the same as those conventionally adopted. In the accomplishment of the underwater ship repair tasks, it should be definitely established that the diver knows how to rig the objects of varying shape correctly, how to tie knots and to handle the hoisting mechanisms and devices.

## CHAPTER 13

## SAFETY RULES WITH REFERENCE TO UNDERWATER SHIP REPAIR TASKS

Independently of the types of work, in the underwater repair of ships the rules of the diving profession must be strictly observed, especially the rules for enforcing safety during the dives. The demands made on the physiology involved in diving work are generally known, therefore we discuss further only the requirements of the safety rules, ensuing from the specifics of individual forms of underwater ship repair tasks.

### Section 68. Safety Rules Applying to Underwater Welding

Since welding under water is done with the aid of electric current, special attention should be paid to observing the safety rules imposed on jobs involving the use of electricity.

The extent of injury by electricity depends on a number of factors--the force of the current, its voltage, duration of effect, resistance of the human organism and particularly on the condition of the skin and nervous system.

The higher the current voltage and the lower the resistance of the human organism and of the clothing worn, the more current can pass through the man's body and injure him more seriously. Electric current with a force higher than 0.1 amp is lethal. Also dangerous is a voltage higher than 12 v in damp facilities and higher than 36 v in dry facilities.

Alternating current is more hazardous to man than direct current. /238

During his work under water, the diver-welder should be insulated against electricity and from the penetration of moisture from outside.

Underwater welding is performed in diver's winter gear in good condition, including mittens, with an electrode holder in proper condition and reliably insulated. The connections to the welding cable must also be carefully insulated.

Injury from electric current in underwater conditions is possible through the metal components of the diving gear or in case of an awkward handling of the electrode holder. One is categorically forbidden to grasp by hand an electrode which is receiving current. One must never place the holder with the electrode, connected to current, on the work object, the work platform or the bottom. Nor should one ever place a live electrode against the diving helmet, since a burn-through is possible.

Reliable constant telephonic contact must be maintained with the diver. If the telephone has gone out of commission, welding operations under water are discontinued.

One should incorporate in the welding circuit a cutoff switch which can be turned on and off only at the order of the diver, and the action taken must be reported to him by phone.

During the work with direct current in underwater conditions, owing to electrolysis, we find a breakdown of the copper parts in the diving gear, and primarily of the diving helmet. To avoid this development, we recommend attaching zinc plate-type shields to the diving suit and helmet; it would also be feasible to cover with rubber or to paint the diving helmet and all copper parts of the diving gear with carbon, ethynol or celluloid lacquer. Breakdowns of the metal components of the gear were not noted during the work with alternating current.

In the performance of welding activities under water in inconvenient locations, a second (backup) diver should be standing by, with suit on but without helmet or burdens. Welding tasks under the ship bilge should be performed only from a work scaffold (sling).

### Section 69. Safety Rules During Underwater Electric-Arc and Oxy-electric Cutting

During the underwater electric-arc and oxy-electric cutting, it is necessary to comply with all of the safety regulations established for underwater electric welding. In addition, during oxy-electric cutting, one must observe the requirements imposed by the safety rules pertaining to handling oxygen equipment and pressurized gases.

The oxygen tanks must be stored in a specially ventilated facility where the temperature does not exceed +35°C. Pressurized inflammable gases, gasoline, kerosene etc. must not be stored together with oxygen.

We recommend that the fuels and lubricants be stored only at a distance of at least 10 meters away from the storage site of the oxygen tanks. In buildings used for storing oxygen, only electric lighting is permitted. All the switches and fuses must be installed on the outside. Smoking or the carrying-in or striking of an open flame in these buildings is forbidden.

During the transport of oxygen tanks, the connecting pipes must be fitted with end caps and covers must be placed over the outlets. Each tank must be moved only on a stretcher by 2 men, or must be hauled on specially designed carts.

Before utilizing the tanks, we verify their proper working condition and the presence of the inspection seal affixed by the Kotlonadzor (Boiler Inspection Agency). During the 1-second scavenging of the tank, the worker should stand to the side of the outlet pipe. The reducing valve and hoses must be in good condition. Reducing valves with worn threads on the union nut must not be put in operation.

Special attention must be diverted to avoiding the admission of grease, dirt, oil, etc. to the oxygen equipment and lines. Damaged hoses sections must be cut off and the remaining parts must be connected with two-ended nipples, following by a reinforcement of the hoses with lashing or special clamps.

### Section 70. Safety Rules Applying to Underwater Gas-Oxygen Cutting

In addition to the safety rules apply to oxy-electric cutting, during the work with an installation for underwater gas-oxygen cutting, the following conditions must be fulfilled.

--the tank containing the gasoline must be separated by at least 5 m from the oxygen tanks;

--the tank must be filled with gasoline in a specially assigned place, and one must see to it that the gas does not get onto one's clothing; during filling in the open air, one must not stand facing the wind;

--the loose connections in the joints of the hoses and equipment are to be located only with the use of soapy water or by ear; to avoid blowing up the equipment, it is forbidden to use flame to check for leaks;

--for the sealing gaskets, one should utilize only asbestos cord soaked with paráffin, while the sealing strips are made of fiber or lead;

--after igniting the cutter at the surface, it should be lowered in such a way that the flame would be directed away from the diver;

--when lighting the cutting tool at the surface, it should be held with head downward and one should stand upwind from it;

--in case of rupture or tearing of the oxygen and gasoline lines, the emergency hose is bent in a loop above the point of breakage, or the pressure valve is shut off;

--in the case of a blowback of the flame, the gas supply is quickly cut off, and then the cutting and heating oxygen valves are closed; and

--one should not permit the accumulation of excess gasoline on the water surface.

### Section 71. Safety Rules in Effect During Underwater Blasting Operations

In the performance of blasting operations underwater, it is necessary to be guided by the safety rules set by the Mining Inspectorate of the USSR. Those permitted to do the blasting tasks include only the diver-demolitions experts, having completed special training and having received the "Standardized Handbook for Demolitions Experts."

The essential requirements imposed by the safety rules can be summarized as the careful handling of high explosives (HE) and a timely warning both to the crew of the ship on which the demolition operations are being conducted, and to the ships which /241
are anchored on the roadsteads (within distances up to 1 mile). It is particularly important that at the time of the explosion, no divers or swimmers would be under water. Therefore prior to the blasting, the boundaries of the hazardous zones are established on the shore and around the water basin.

All the participants in the operation should be well instructed, should know the procedures and how to handle the HE. Permission is granted to conduct the blasting operations only from an ocean-going sloop in good condition, while in winter, it is done from the permanent ice. The conduct of blasting operations from self-propelled equipment is <u>forbidden</u>.

The sloop should contain only the demolition worker and the oarsmen. The demolition worker should set off the charges from his position in the stern. The charges are also stored in the stern. The permissible number of charges is not to exceed 10, with a total weight up to 40 kg. However, we recommend that only the required number of charges be carried on the sloop.

During the towing to the point of operations with the diving boat, the sloop should be separated by 6 m from the boat. The demolition worker hands the charges to the diver (at this time, the sloop is permitted to come close to the diving boat).

The diver should carry the charges in his hands and check that the wires running from the charges do not become tangled on any object, hoses or the signal rope. At the same time, the demolition expert should pay out the lines in such a way that they would not become tangled with the diving helmet or with the signal rope.

If the charges are light in weight, the diver is given several charges in a basket fitted with special recesses. Having set the charges, the diver ties the lines for a certain distance, e.g. beyond the support arm, and emerges from the water. At this time, he should make certain that he does not move the charges and that the lines do not get caught.

One must not rearrange or prepare the charges in the sloop, nor is one allowed to check the electric detonators, repair the insulation on the charges, to start a fire or to smoke.

The main lines can be connected with blasting machine only after the charges have been set and the diver has climbed out of the water. Unexploded charges must be raised cautiously, just as during placement, and are to be carried out only in one's hands. The unexploded charges are destroyed by blasting or are sunk in great depths. The blasting operations are conducted during the day time and in calm weather (wave action not more than two points, wind force not greater than four points).

## Section 72. Safety Rules Pertaining to Underwater Painting

During work performed with coal-tar lacquer or ethynol paints, it is necessary to use caution, since the materials contained in them are harmful to one's health, can easily be ignited, and in addition, ethynol lacquer is highly explosive.

The diver should prepare the equipment and the paints in waterproof protective clothing, goggles and canvas mittens. One is forbidden to smoke, start a fire or use matches in the places for storing lacquers, or during the process of preparing the paints for application. Fire extinguishants must be placed in readiness at the surface (e.g. sand, fire extinguisher).

The packing under the Kuzbas lacquer and the ethynol paints should always be kept clean by steaming, and washing with hot water. Lacquers can be transported only in sealed packaging. The paints are to be prepared directly at the object to be painted, and in quantities not exceeding one day's requirement. Any surplus paint, especially ethynol, should be discarded by burying in vacant land or dumping in a deep place.

At the work site, there should be a medicine chest including turpentine, potable soda, gauze etc. To avoid poisoning, one must never eat at the painting sites in diving costume, with unwashed hands. In the case of injury to the mucous membrane of the eyes by the paint, they must be washed immediately with a 2% solution of potable soda on a clean cloth. If the paint has contacted the skin of the hands or face, it is necessary to wipe it off immediately with gauze soaked in turpentine and then to wash with warm water and soap. The distillation of the volatile substances from the ethynol and coal-tar lacquer is conducted only in an electric heater.

## Section 73. Safety Rules Pertaining to Underwater Gamma-Ray Radiography

During the underwater radiography, it is necessary to observe the safety rules and the labor regulations adopted for industrial radiography. Taking into account the specifics of working under water, it is also necessary to comply with the following requirements. /243

The ampule should be transferred from the container and the holder should be loaded only in an insulated area directly prior to its being mounted for the radioscopy; at this time, the operator should be provided with a lead shield.

The loaded holder is lowered to the diver only after setting the cartridge for the section to be x-rayed. During the loading of the holder with the ampule and its delivery to the diver, those in the area should be separated by at least 3 m from the source of the gamma-rays. One is forbidden from grasping by hand the can containing the ampule. In case of necessity, one utilizes tongs with a length of at least 25 cm. During the mounting of the ampule on the section to be x-rayed, the diver must grasp the holder by the base.

In the breaks between the x-raying under water, the ampule is stored only in a special lead container. Periodically (at least once a month), the can is opened for inspection and the deposit of salts on its interior surface is removed. Should the walls have become broken under the effect of the gamma-rays, the can is replaced.

The divers involved with radiography under water should pass a quarterly medical examination and have written permission for handling radioactive material and for performing the tasks.

## Section 74. **Safety Rules Applicable to Other Underwater Ship Repair Tasks**

In the performance of the rigging operations, the cables which are being utilized should be marked (should have tags or marks) and be maintained in good condition. Workers are not allowed to use damaged cables, lines or various devices in improper condition. The pulleys, jacks, winches and the like should be accompanied by the tables indicating load-lifting /244 capacity and must be in good operating condition.

To avoid the shifting or breaking loose of loads, they must be raised and lowered uniformly, without jolts and only at the diver's command. One should never stand under a load which is being moved.

In the event of a malfunction suddenly detected in the performance of the rigging tasks, the first person who has noted the trouble must give the order "Stop" which is observed immediately.

During the performance of the hull repair tasks under water, one observes the general rules imposed on the diving service as well as the rules pertaining to working with mechanized equipment. Specifically, during the work breaks, the working tool must be removed from the chuck of the pneumatic hammer, drill etc. in order to avoid accidents occurring from a sudden starting of the tool.

The requirements imposed by the safety rules in the performance of the underwater assembling, preparatory and other tasks do not differ in any respect from the general requirements involved in the accomplishment of the same duties at the surface. In the completion of these tasks, it is therefore necessary to be guided by the general requirements imposed by the safety rules and the regulations pertaining to the diving service.

In the operations involved in unsealing a ship's hull, e.g. during the repair of the propeller installation, the bottom fittings etc., one should set up a 24 hour watch at the water-pumping equipment, being prepared to use them immediately in emergency and other cases, established in relationship to the actual conditions (e.g., in case of excess water leakage and so forth).

## APPENDICES

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Appendix 1

### PERMISSIBLE CABLE LOADS

| Cable diameter, mm | Weight, kg | Permissible load, $kg/cm^2$ |
|---|---|---|
| 20 | 400 | 127,4 |
| 30 | 1000 | 141,5 |
| 40 | 1500 | 119,4 |
| 50 | 2500 | 127,4 |
| 60 | 3500 | 127,4 |
| 70 | 5000 | 129,9 |
| 80 | 6500 | 129,3 |
| 90 | 9000 | 141,5 |
| 100 | 12000 | 152,8 |

Remark. The steel cables with an organic core of the TK type are regulated by the various GOST (State Standards); in underwater ship repair, use is most often made of the cables complying with GOST 3071-55 and GOST 3072-55.

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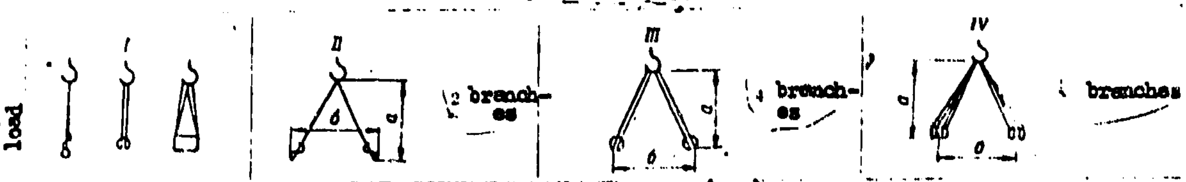
CHOOSING THE DIAMETERS OF CABLES. RIGGING SYSTEMS FOR HOISTING LOADS




| Weight (tons) of hoisted load | Number of branches | | | Laying (a:b) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 4 | 1:1 | 1:1.5 | 1:2 | 1:1 | 1:1.5 | 1:2 | 1:1 | 1:1.5 | 1:2 |
| | Cable diameter, mm | | | | | | | | | | | |
| 1 | 15.5 | 11 | 11 | 11 | 13 | — | 11 | 11 | 11 | 11 | 11 | 11 |
| 2 | 19.5 | 15.5 | 11 | 15.5 | 17.5 | — | 13 | 13 | 15.5 | 11 | 11 | 11 |
| 3 | 24 | 17.5 | 13 | 17.5 | 19.5 | — | 15.5 | 17.5 | 17.5 | 11 | 11 | 11 |
| 4 | 30.5 | 19.5 | 15.5 | 19.5 | 24 | — | 17.5 | 19.5 | 19.5 | 11 | 13 | 15.5 |
| 5 | — | 22 | 15.5 | 24 | — | — | 19.5 | 22 | 22 | 15.5 | 15.5 | 17.5 |
| 6 | — | 24 | 15.5 | — | — | — | 22 | 24 | 24 | 15.5 | 17.5 | 17.5 |
| 7 | — | 26 | 17.5 | — | — | — | 24 | 26 | 26 | 17.5 | 17.5 | 19.5 |
| 8 | — | 28.5 | 19.5 | — | — | — | 26 | 26 | 28 | 19.5 | 19.5 | 19.5 |
| 9 | — | 30.5 | 22 | — | — | — | 28 | 28 | 30.5 | 19.5 | 19.5 | 22 |
| 10 | — | 32.5 | 22 | — | — | — | 28 | 30.5 | 32.5 | 19.5 | 22 | 22 |
| 11 | — | [illegible] | 24 | — | — | — | 30.5 | 30.5 | 32.5 | 22 | 22 | 24 |
| 12 | — | — | 26 | — | — | — | 30.5 | 32.5 | 35 | 22 | 24 | 24 |
| 13 | — | — | 26 | — | — | — | 32.5 | 32.5 | — | 22 | 24 | [illegible] |
| 14 | — | — | 28.5 | — | — | — | 32.5 | 35 | — | 24 | — | [illegible] |
| 15 | — | — | 28.5 | — | — | — | 35 | — | — | [illegible] | — | [illegible] |

Remark. The table is compiled for cables having a provisional resistance of 130 kg/mm$^2$ in accordance with GOST 3071-55 with a reserve factor of 7-9. The number of operating arms of the slings in the calculation has been adopted: for system III--3 units; for system IV--6 units; and for systems I and II--based on actual number of arms.

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DETERMINATION OF PERMISSIBLE LOADS ON A CABLE BASED ON ITS CIRCUMFERENCE
(based on Naval ASS(expansion unknown) data)

| Type of cable | Breaking load | Working load |
|---|---|---|
| Hard steel. . . . . . | $P = 1,8\ C^2$ | $P = 0,8\ C^2$ |
| Semihard " | $P = 1,8\ C^2$ | $P = 0,8\ C^2$ |
| Flexible " | $P = 1,0\ C^2$ | $P = 0,65\ C^2$ |
| Thick flexible steel. . . | $P = 3,3\ C^2$ | $P = 0,5\ C^2$ |

Remark. P-- energy, kg; C = cable circumference, mm.

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# WEIGHT OF HIGH EXPLOSIVE (HE) FOR REMOVAL OF SCREW PROPELLERS

| Weight of screw propeller, kg | Total HE weight (g) for moving the propeller: steel | bronze | cast iron | Number of charges |
|---|---|---|---|---|
| [illegible] | [illegible] | 21 | [illegible] | 2 |
| [illegible] | [illegible] | 28 | [illegible] | 2 |
| [illegible] | [illegible] | [illegible] | [illegible] | 2 |
| [illegible] | 32 | 39 | [illegible] | 2 |
| 700 | 38 | 44 | 52 | 2 |
| 800 | 41 | 52 | 60 | 2 |
| 900 | 48 | 60 | [illegible] | 2 |
| 1000 | 54 | 65 | [illegible] | 2 |
| 1100 | 60 | 71 | 84 | 2 |
| 1200 | 65 | 80 | [illegible] | 2 |
| 1300 | 70 | 85 | 98 | 2 |
| 1400 | 75 | 92 | 105 | 2 |
| 1500 | 80 | 100 | 115 | 2 |
| 1600 | 85 | 105 | 121 | 2 |
| 1700 | 90 | 110 | 132 | 2 |
| 1800 | 95 | 115 | 140 | 2 |
| 1900 | 100 | 120 | 145 | 2 |
| 2000 | 105 | 126 | 155 | 3 |
| 2200 | 111 | 135 | 155 | 3 |
| 2400 | 120 | 145 | 175 | 3 |
| 2500 | 125 | 153 | 184 | 3 |
| 2800 | 141 | 171 | 201 | 3 |
| 3000 | 150 | 180 | 213 | 3 |
| 3500 | 170 | 200 | 240 | 3 |
| 4000 | 190 | 230 | 250 | 3—4 |
| 4500 | 210 | 250 | 265 | 3—4 |
| 5000 | 230 | 280 | 320 | 3—4 |
| 5500 | 248 | 300 | 340 | 3—4 |
| 6000 | 260 | 310 | 350 | 3—4 |
| 6500 | 280 | 330 | 370 | 3—4 |
| 7000 | [illegible] | 350 | 400 | 3—4 |
| 7500 | 310 | 370 | 410 | 4 |
| 8000 | 320 | 390 | 420 | 4 |
| 8500 | 340 | 410 | 450 | 4 |
| 9000 | 350 | 430 | 485 | 4 |
| 9500 | 350 | 450 | 500 | 4 |
| 10000 | 380 | 470 | 520 | 4 |

Remarks. 1. The weight of one charge is established as the ratio of HE weight to the number of the charges.

2. The lines delineate the limits of the critical (safe) weights of the HE depending on distance, given the same thickness of sheathing.

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## CRITICAL WEIGHT (IN GRAMS) OF HE FOR REMOVAL OF SCREW PROPELLERS

| Thickness in mm of ship hull's sheathing sheet | Submergence depth (m) of charges: 2 | | | | 4 | | | | 6 | | | | 8 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distance (m) from charge to ship hull's sheathing (planking) | | | | | | | | | | | | | | | |
| | 1,2 | 1,8 | 2,4 | 3,0 | 1,2 | 1,8 | 2,4 | 3,0 | 1,2 | 1,8 | 2,4 | 3,0 | 1,2 | 1,8 | [illegible] | [illegible] |
| 5 | 90 | 100 | 110 | 115 | 110 | 125 | 140 | 150 | 135 | 150 | 170 | 180 | 150 | 175 | [illegible] | 210 |
| 6 | 110 | 115 | 130 | 140 | 130 | 150 | 170 | 180 | 160 | 180 | 200 | 220 | 180 | 210 | 230 | 250 |
| 7 | 125 | 135 | 150 | 160 | 150 | 175 | 195 | 210 | 185 | 210 | 230 | 250 | 210 | 250 | 270 | [illegible] |
| 8 | 140 | 155 | 170 | 185 | 170 | 200 | 225 | 240 | 215 | 240 | 265 | 290 | 240 | 280 | 305 | 335 |
| 10 | 180 | 195 | 215 | 230 | 215 | 250 | 275 | 300 | 265 | 300 | 330 | 360 | [illegible] | 345 | 380 | 420 |
| 12 | 215 | 230 | 255 | 270 | 255 | 300 | 335 | 360 | 320 | 350 | 400 | 435 | 370 | 420 | 460 | 505 |
| 14 | 250 | 270 | 300 | 320 | 300 | 350 | 390 | 420 | 370 | 420 | 470 | 510 | 420 | [illegible] | 510 | [illegible] |

Appendix 6

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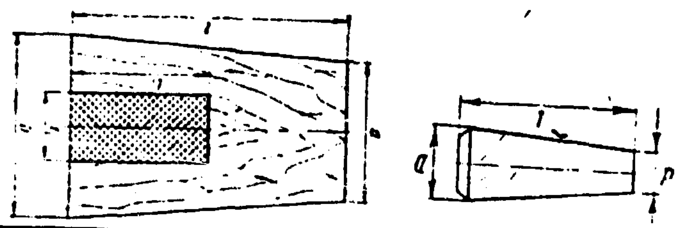
## WOODEN (PINE) PLUGS FOR CLOSING THE SIDE OPENINGS



| Diameter (mm) of hole being covered | Size of plug, mm | | | Weight (kg) of plug | Size of opening in mm for pouring cement | |
|---|---|---|---|---|---|---|
| | $d$ | $D$ | $l$ | | $l_1$ | $d_i$ |
| 50 | 40 | 72 | 175 | 0,3 | — | — |
| 100 | 80 | 123 | 240 | 1,3 | — | — |
| 150 | 120 | 174 | 300 | 3,5 | — | — |
| 200 | 160 | 225 | 360 | 7,3 | — | — |
| 250 | 200 | 276 | 425 | 13,3 | — | — |
| 300 | 240 | 326 | 480 | 21,3 | 210 | 120 |
| 350 | 280 | 375 | 525 | 31,0 | 260 | 140 |
| 400 | 320 | 420 | 560 | 42,3 | 280 | 160 |
| 450 | 360 | 465 | 585 | 54,8 | 290 | 180 |
| 500 | 400 | 508 | 600 | 68,3 | 300 | 200 |

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# CHEMICAL COMPOSITION OF ELECTRODE WIRE USED DURING UNDERWATER WELDING (GOST 2246-60)

| Brand of wire and purpose | Content of elements, % | | | | | | |
|---|---|---|---|---|---|---|---|
| | manganese | silicon | carbon | chromium | nickel | sulfur | phosphorus |
| | | | not more than | | | | |
| Sv-08, for seams of increased strength & viscosity (manual welding) | 0,35—0,6 | Not more than Не более 0,03 | 0,1 | 0,15 | 0,3 | 0.04 | 0,04 |
| Sv-08A, for seams of important designs (manual welding) | 0,35—0,6 | Not more than Не более 0,03 | 0,1 | 0,1 | 0,25 | 0,03 | 0,03 |
| SV-12GS, for seams of important designs (semiautomatic welding) | 0,8—1,1 | 0,6—0,9 | 0,14 | 0,2 | 0,3 | 0,03 | 0,03 |
| Sv-08G2S, for seams of important designs (semiautomatic welding) | 1,8—2,1 | 0,7—0,95 | 0,11 | 0,2 | 0,25 | 0,03 | 0,03 |

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## COMPOSITION OF ELECTRODE COATINGS (COVERINGS) FOR UNDERWATER WELDING AND CUTTING
(in percentages by weight)

| Components | Brand of electrode | | | |
|---|---|---|---|---|
| | EPS-5 | EPS-52 | EPO-55 | EPR-1 |
| Titanium dioxide . . . . | 35 | 3 | 25 | — |
| Feldspar . . . . . . . . | 10 | 20 | — | 18 |
| Marble . . . . . . . . . | 10 | — | 20 | 12 |
| Iron ore . . . . . . . . . | — | 28 | — | — |
| Zirconium ore . . . . . . | 5 | — | — | — |
| Ferromanganese | 5 | 30 | 8 | — |
| Ferrotitanium | 12 | 5 | 12 | — |
| Ferrosilicium | 3 | — | 5 | 17 |
| Powdered iron | — | — | 30 | — |
| Starch | — | 5 | — | — |
| Sawdust | — | — | — | 17 |
| Liquid glass to weight of dry batch . . . . . . | 20 | 20–25 | 20–26 | 35 |

Remarks.
1. The EPR-1 electrodes are designed for oxyelectric cutting.
2. The EPO-55 electrodes are manufactured on a base of potassium liquid glass.
3. In the EPS-5 and EPR-1 electrodes, the liqudi glass enters the percentual content of the mixture.
4. Waterproofing of the elctrodes—solution of copolymer of vinyl chloride with vinyl acetate in dichloroethane.
5. At the present time, the EPS-52 electrodes are produced without an organic component.

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# TECHNICAL SPECIFICATIONS OF ELECTRODES USED FOR UNDERWATER WELDING AND CUTTING

| Type of electrodes | Diameter (mm) of electrode rod | Thickness (mm) of coating on side | Current type and polarity | Recommended current conditions (amps) for working in downhand position | Weld seam coefficient, g/amps·hr | Tentative shear resistance, $kg/mm^2$ | Angle of bending, degrees | Impact viscosity, $kgm/cm^2$ |
|---|---|---|---|---|---|---|---|---|
| EPS-5 | 4<br>5 | 0,7–0,9<br>0,9–1,0 | Direct, forward and reversed | 160–220<br>200–275 | 9,2–9,8 | 38–42 | To 130 | – |
| EPS-52 | 4<br>5 | 0,8–1,0<br>0,9–1,1 | Direct, forward, alternating | 160–200<br>200–250 | 9,8–10,4 | 39–42 | To 130 | 7–9 |
| EPO-55 | 4<br>5 | 0,9–1,1<br>1,1–1,3 | Direct, forward and reversed | 210–260<br>300–320 | 6,7–9,7 | 42–52 | To 124 | 4–5 |
| EPR-1 | Tube 7/2 | 0,8–1,0 | Direct, forward | 200–350* | ... | ... | | |

* The current is selected depending on thickness of metal being cut.

TECHNICAL SPECIFICATIONS OF STATIONARY MODELS OF WELDING MACHINES OPERATING OF DIRECT CURRENT

| Nomenclature | SP-3-IV | SAM-250 & SAM-250-1 | SAM-400 | SAM-400-1 | SG-3 | SG-3s-II | SG-4b-IV | PSM-1000 |
|---|---|---|---|---|---|---|---|---|
| Type of generator | SP-3-IV | SG-2-IV / SG-2-VI | SGP-3-VI | SGP-3-VI | SG-3 | SG-3s-II | SG-4b-IV | SG-1000 |
| Current force, amps | | | | | | | | |
| at PR - 100% | 500 | 250 | 400 | 400 | 500 | 500 | 500 | 1000 |
| at PR - 65% | 700 | 300 | 500 | 500 | — | — | — | — |
| Limits of current regulation, amps | 120—800 | 70—340 | 120—600 | 120—600 | — | — | — | — |
| Idling voltage, v | 68 | 76 | 90 | 90 | 60 | 60 | 60 | 60 |
| Rated voltage, v | 40 | 30 | 40 | 40 | 60 | 60 | 60 | 60 |
| Power, kw, under prolonged conditions | 20 | 7,5 | 16 | 16 | 30 | 30 | 30 | 60 |
| Number of rpm | 1500 | 1560 | 1460 | 1500 | 1430 | 1430 | 1430 | 1470 |
| Number of posts | 1 | 1 | 1 | 1 | 4 | 4 | 9 | 9 |
| Type of electric motor | APN | PN-100 | MAP-82-73/4 | PN-290 | MA-[illegible] MEA 22/40 | Three-phase | [illegible]-501/4 | VDE 75-4, AV-91/4 |
| Power, kw, of electric motor | 46,4 | 14,25 | 32 | 32 | 37 | 36 | 75 | 75 |
| Dimensions, mm | | | | | | | | |
| length | | 1619 | 1770 | 1980 | 2050 | 2050 | 2363 | 1470 |
| width | | 550 | 650 | 650 | 765 | 765 | 985 | 855 |
| height | | 915/935 | 920 | 940 | 690 | 690 | 816 | 910 |
| Weight, kg. of apparatus | 1500 | 850/825 | 1450 | 1600 | 1600 | 1600 | 2000 | 1700 |

Remark. P = recurrent-short term regime of generator's operation (i.e. that percentage of time when the generator is under load; e.g. P = 65% in a 5-minute cycle signifies that each 5 minutes, the generator is operating under load for 3 minutes, and is running idle for 2 minutes.)

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## TECHNICAL SPECIFICATIONS OF PORTABLE WELDING TRANSFORMERS

| Nomenclature | Type of transformer: PS-500 — For manual welding & cutting | PSO-500 — For manual welding & cutting | PSU-500* — For manual welding (falling curve) | PSU-500* — For semi-automatic welding in $CO_2$ | D-3** — For manual welding & cutting |
|---|---|---|---|---|---|
| Type of generator | GS-500 | GSO-500 | GSU-500 | GSU-500 | SMG-3V-III |
| Power, kw . . . . | 16 | 16 | 16 | 16 | 30 |
| Idling voltage, v. | 90 | 85 | 80 | 48 | 60 |
| Rated voltage, v. | 40 | 40 | 40 | 40 | 60 |
| Current force, amps: at P = 100% | 400 | 400 | 400 | 400 | [illegible] |
| at P = 65% | 500 | 500 | 500 | 500 | 600 |
| Limits of regulating current force, amps. | 120 - 600 | 120 - 600 | 120 - 600 | 60 - 500 | 120 - [illegible] |
| Type of electric motor . . . . . . | A-72/4 | A-72/4 | AV-71/2 | AV-71/2 | MP-523 |
| Power of electric motor, kw . . . | 28 | 28 | 28 | 28 | [illegible] |
| Number of rpm . . . | 1450 | 1450 | 2900 | 2900 | 1430 |
| Number of posts . . . | 1 | 1 | 1 | 1 | 5 |
| Dimensions, mm: length . . . . . . . | 1100 | 1275 | 1065 | 1065 | 2500 |
| width . . . . . . . . | 770 | 770 | 650 | 650 | 920 |
| height . . . . . . . | 1110 | 1080 | 915 | 915 | 1207 |
| Weight, kg. . . . . . | 950 | 780 | 510 | 510 | [illegible] |

* The PSU-500 transformers are manufactured with rigid and falling external characteristics. The transformer permits switching to manual or automatic (semiautomatic) welding.

** The D-3 transformer is one of the motor-generators mounted on a rigid frame, placed on rollers. The electric motor and the generator are connected with a flexible coupling.

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# TECHNICAL SPECIFICATIONS OF AUTONOMOUS WELDING MACHINES

| Nomenclature | Type of installation | | | | | |
|---|---|---|---|---|---|---|
| | SPAZ-3a | PAS-400 | PAS-400-VI | PAS-400-VIII | ASD-3-I | ASDP-500 |
| **Generator** | | | | | | |
| Type | SGP-3-I | SGP-3-II | SGP-3-VI | SGP-3-VIII | SGP-3-VIII | SGP-3-VIII |
| Power, kw | 16 | 15 | 15 | 15 | 16 | 16 |
| Idling (no-load) voltage, v. | 90 | 90 | 105 | 90 | 90 | 90 |
| Rated voltage, v. | 40 | 40 | 40 | 40 | 40 | 40 |
| Rated current, amps: | | | | | | |
| at P = 100% | 400 | 400 | 400 | 400 | 400 | 400 |
| at P = 65% | 500 | 500 | 500 | 500 | 590 | 500 |
| Regulation limits, amps. | 120-600 | 120-600 | 120-600 | 120-600 | 120-500 | 120-600 |
| Number of rpm | 1700 | 1700 | 1600 | 1600 | 1600 | 1600 |
| Number of posts | 1 | 1 | 1 | 1 | 1 | 1 |
| **Engine** | | | | | | |
| Type | ZIL-5 | ZIL-5M | ZIL-120 | ZIL-120 | YAAZ-204G | YAAZ-204G |
| Power, hp | 60 | 90 | 90 | 90 | 60 | 60 |
| Type of fuel | Vehicle gas A 66 | Vehicle gas A 56 | Vehicle gas A-66 | Vehicle gas A 56 | Diesel fuel | Diesel fuel |
| Tank capacity, liters | 35 | 35 | 50 | 50 | 240 | 240 |
| Number of rpm | 2100 | 2400 | 1600 | 1600 | 1500 | 1500 |
| Overall dimensions of rig, mm | | | | | | |
| Length | 2810 | 2810 | 2870 | 2870 | 2820 | 2820 |
| Width | 880 | 880 | 880 | 880 | 1100 | 1100 |
| Height | 1920 | 1920 | 1920 | 1920 | 2100 | 2100 |
| Weight of apparatus, kg | 1900 | Around 2000 | 1960 | 1960 | 2500 | 2500 |

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## TECHNICAL SPECIFICATIONS OF WELDING EQUIPMENT USING AC, SUITABLE FOR UNDERWATER WELDING (CUTTING)

| Item | Types of units | | | | |
|---|---|---|---|---|---|
| | STE-32 | STE-34 | STN-450 | STN-500 | STN-700 |
| Power, kva. . . . | 29 | 31 | 40 | 32 | 45,5 |
| PR ( P), % . . | 65 | 65 | 65 | 65 | 65 |
| Current force at given P, amps. . | 450 | 500 | 450 | 500 | 700 |
| Primary voltage, v. | 220 or 380 or 500 | 220 or 380 | 220 or 380 | 220 or 380 | 220 or 380 |
| Secondary voltage, v. . . | 65 | 60 | 90/70 | 60 | 60 |
| Rated voltage, v. . | 30 | 30 | 30 | 30 | 35 |
| cos at given regime. . . . . | 0,60 | 0,52 | 0,52 | 0,54 | 0,54 |
| Efficiency, % . . | 83 | 81 | 85 | 86 | 85 |
| Limits of current control, amps. . . | 150—500 | 150—700 | 150—800 | 150—700 | 200—900 |
| Dimensions (mm) of transformer: | | | | | |
| height . . . . | 677 | 550 | 850 | 840 | 840 |
| width . . . . | 377 | 360 | 420 | 379 | 429 |
| length . . . . | 668 | 600 | 840 | 772 | 796 |
| Dimensions of current regulator, mm: | | | | | |
| height . . . . | 623 | 669 | — | — | — |
| width . . . . . | 317 | 320 | — | — | — |
| length . . . . | 515 | 515 | — | — | — |
| Weight of transformer, kg. | 210 | 200 | 350 | 260 | 380 |
| Weight of regulator, kg . . . . | 120 | 120 | — | — | — |

Remarks: 1. The welding rigs with aluminum STN-500-II and STN-700-II coils are not suitable for marine conditions.

2. The type STN rigs are manufactured in a single frame model, with a built-in current regulator; therefore the dimensions and weight are given as the same, in the line for the transformers.

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## TECHNICAL SPECIFICATIONS OF GASCLINE USED IN UNDERWATER CUTTING

| Item | Specific weight, g/cm³ | Octane rating | Heat of combustion, cal/kg | Start of boiling not under, °C | End of boiling not higher than, °C | Actual content of resins, mg | Remark |
|---|---|---|---|---|---|---|---|
| Aviation gasoline | | | | | | | |
| (Baku) B-78 . . | 0,745 | 78 | 11 000 | 40 | 150 | 2,0 | GOST 1012—54 |
| Aviation gas.B-70 | 0,755 | 70 | — | 40—75 | 170 | 3,0 | |
| " " KB-70 | 0,730 | 70 | — | 35 | 175 | 6,0 | |
| Motor vehicle gasoline, light 1st grade (Groznenskiy) | 0,737 | — | 10 910 | 52 | 175 | 7,0 | GOST 2084—56 |
| Motor vehicle, cracked gasoline (Groznenskiy) | 0.747 | — | 10 840 | 45 | 225 | Inconstant | |

Appendix 15
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## CONDITIONS AND TECHNICAL-ECONOMIC INDEXES OF GASOLINE-OXYGEN CUTTING UNDERWATER WITH THE BUPR RIG

| Thickness of metal, mm | Working pressure, atm | | | Cutting speed, m/hr | Consumption of gasoline & oxygen in 1 hr (averages) | | | Consumption of gasoline & oxygen per running m of cut (averaged values) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | gasoline | heating oxygen | cutting oxygen | | gasoline, g | heating oxygen, m³ | cutting oxygen, m³ | gasoline, g | heating oxygen, liters | cutting oxygen, liters |
| 10 | 7 | 7 | 7 | To 22 | 3200 | 12,6 | 9,5 | 170 | 630 | 175 |
| 20 | 7 | 7 | 7 | To 16 | 3800 | 14,0 | 10,1 | 230 | 930 | 670 |
| 40 | 7 | 8 | 8 | To 14 | 5050 | 16,3 | 11,4 | 380 | 1250 | 875 |
| 50 | 7 | 8 | 9 | To 12 | 6800 | 17,7 | 12,1 | 600 | 1600 | 1100 |
| 80 | 8 | 9 | 11 | To 9 | 7200 | 18,4 | 14,7 | 900 | 2300 | 1800 |
| 90 | 8 | 9 | 12 | To 8 | 7500 | 18,5 | 17,5 | 1050 | 2600 | 2500 |
| 100 | 8 | 9 | 12 | To 6,5 | 7800 | 18,8 | 17,5 | 1300 | 3100 | 2900 |
| Packs | | | | | | | | | | |
| 50 | 8 | 8 | 10 | To 10 | 6900 | 18,0 | 13,4 | 760 | 2000 | 1500 |
| 67 | 8 | 8 | 10 | To 9,0 | 6900 | 18,0 | 13,4 | 820 | 2200 | 1675 |
| 95 | 8 | 9 | 12 | To 5,5 | 7800 | 19,0 | 17,5 | 1500 | 3800 | 3500 |

Remarks: 1. The table is compiled from calculating a cutting depth to 10m and hoses' length of 30 m.

2. With an increase in the cutting depth each 10 m, the working pressure of the gases and gasoline increases by 1 atm.

3. With an increase in the length of hoses, each 30 m, the pressure of the gases and gasoline increases by 0.75 atm.

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## PRODUCTIVITY OF THE ELECTRIC ARC AND OXYELECTRIC CUTTING OF STEEL UNDER WATER

| Type of cutting | Parameters | Thickness of metal, mm: 5–10 | 10–15 | 15–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–80 | 80–100 |
|---|---|---|---|---|---|---|---|---|---|---|
| Electric arc | Cutting time, min.. | 45–78 | 78–108 | 108–156 | 156–210 | 210–270 | 270–350 | 350–420 | | |
| | Consumption of electrodes, units | 3–7 | 7–15 | 15–40 | 50–80 | 80–120 | 120–150 | 150–200 | | |
| Oxyelectric | Cutting time, min. | 10–23 | 23–33 | 33–45 | 45–60 | 60–90 | 90–105 | 105–120 | 120–145 | 145–180 |
| | Oxygen consumption liters. | 350–400 | 400–500 | 500–600 | 600–700 | 700–1080 | 1080–1485 | 1485–1620 | 1620–2100 | 2100–2840 |
| | Consumption of electrodes, units. | 4–5 | 5–6 | 6–8 | 8–10 | 10–12 | 12–15 | 15–18 | 18–21 | 21–30 |

Remark. The table is compiled based on cutting 1 running meter at a depth up to 10 meters.

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## CHEMICAL COMPOSITION OF THE PIPE MATERIAL FOR OXYELECTRIC CUTTING UNDER WATER (GOST 1050-60)

| Type of tube, its dimensions in mm | Contents of elements, %: carbon | manganese | silicon | chromium | nickel | sulfur | phosphorus |
|---|---|---|---|---|---|---|---|
| | | | | not more than | | | |
| Steel / 10, 6×2.5 | 0,7–0,14 | 0,35–0,65 | 0,17–0,37 | 0,15 | 0,25 | 0,04 | 0,035 |

Appendix 18

CONDITIONS FOR UNDERWATER OXYELECTRIC CUTTING AT DEPTH UP TO 10 METERS

| Thickness of metal, mm | Current force, amps | Working pressure of oxygen, kg/cm$^2$ |
|---|---|---|
| 5—10 | 200 | 1,5—2,0 |
| 10—15 | 220 | 2,0—3,0 |
| 15—20 | 250 | 3,0—4,5 |
| 20—30 | 275 | 4,5—5,5 |
| 30—40 | 300 | 5,5—6,0 |
| 40—50 | 320 | 6,0—6,5 |
| 50—60 | 350 | 6,5—7,0 |
| 60—80 | 350 | 7,0—9,0 |
| 80—100 | 350 | 9,0—11,0 |
| Over 100 | 400 | 11,0—14,0 |

Remarks: 1. With an increase in depth, each 10 meters the oxygen pressure increases by 1 atm.

2. With an increase in the length of the hoses, every 30 m the oxygen pressure increases by 0.75 atm.

Appendix 19

RECOMMENDED CONDITIONS FOR UNDERWATER SEMIAUTOMATIC WELDING WITH UNSHIELDED ARC, WITH AN ELECTRODE WIRE 1,2 mm IN DIAMETER /263

| Parameter | Units of measurement | Position in space | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | downhand | | | | | vertical | overhead |
| Depth | meters | 10 | 15 | 20 | 40 | 60 | 15 | 15 |
| Current force | amps | 180—220 | 190—220 | 190—200 | 180—200 | 180—200 | 160—180 | 160—180 |
| No-load voltage* | volts | 75—76 | 75—76 | 75—76 | 85 | 90 | 76 | 76 |
| Rate of feeding the wire | In standard units of scale of semiautomatic rig** | 12—13 | 13—14 | 14—15 | 20—21 | 20 21 | 12 14 | 12 13 |
| Pressure of gas | atm | 1,1 | 1,6 | 2,1 | 4,1 | 6,3 | 1,6 | 1,6 |

* The no-load voltage is given for the GS-500 generator, connected according to the factory circuit at network length of 300 m (2 X 150 m).

** Conventional units of the scale are shown for the semiautomatic machine, PPSR-300-2.

Appendix 20

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MECHANICAL PROPERTIES OF COMPOUNDS JOINED BY SEMI-AUTOMATIC WELDING WITH AN OPEN ARC UNDER WATER

| Parameter | Depth of submergence, m | | | |
|---|---|---|---|---|
| | 10 | 20 | 40 | 60 |
| Strength limit, $kg/mm^2$ . . . . . . | $\frac{37.5-42.5}{40,8}$ | $\frac{41.2-43.7}{42,6}$ | $\frac{37,0-38,6}{38,2}$ | $\frac{37.3-42.5}{40}$ |
| Angle of bend, degrees | $\frac{30-50}{45}$ | $\frac{60-95}{8[illegible]}$ | — | — |
| Impact viscosity, $kgm/cm^2$ . . . . . | $\frac{1,5-6,7}{5,7}$ | $\frac{7,2-9,7}{8,4}$ | — | — |

Remark. The numerator refers to the limits of indexes' fluctuations; the denominator refers to the average value of indexes.

Appendix 21

PRELIMINARY DATA ON REGIMES AND PRODUCTIVITY OF UNDERWATER SEMIAUTOMATIC OXYELECTRIC CUTTING*

| Thickness of metal, mm | Current force, amps | Rate of feeding wire, in conventional units of the scale** | Oxygen pressure, atm | Rate of cutting, m/hr |
|---|---|---|---|---|
| 10 | 190–280 | 25–27 | 7–10 | 10–12 |
| 15 | 210–280 | 25–27 | 7–10 | 7,3–11,5 |
| 25 | 250–300 | 25–27 | 8–10 | 2,5 |
| [illegible] | 300–320 | 30–40 | 12–14 | 1,5 |

* The table was compiled from calculating work with an electrode having a diameter of 1.2 mm, $\alpha = 18^{\circ}$, at depth up to 10 m.

** Conventional units of the scale are shown for the PPSR-300-2 semiautomatic rig.

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## SPECIFICATIONS OF SPECIALIZED PNEUMATIC TOOL

| Parameter | Wrench (GOST 10210-62) | Angular drilling machine (GOST 10212-62) | Cutting shears |
|---|---|---|---|
| Purpose . . . . . . . . | Tightening & loosening bolts & nuts | Drilling, reaming & countersinking of holes in metal | Rectilinear & shaped cutting of sheet metal |
| Type of engine . . . | Pneumatic rotor | Pneumatic rotor | Pneumatic rotor |
| Working pressure of compressed air, atm | 5–6 | 5 | 5 |
| Power of pressure engine, hp . . . . . . | 0,6 | 1,75 | 0,5 |
| Gear ratio of reducer . . . | 7,26 | 6,5 | 6 |
| Number of spindle rpm: | | | |
| idling . . . . . | 965 | 300 | — |
| operating . . . . | — | 265 | — |
| Number of strokes/min | 1600 | | |
| Maximal diameter of bolts and nuts being tightened, mm . . . . . . | 32 | | |
| Maximum diameter of drilling, mm . . . . . | | 23 | |
| Maximum diameter of reamings, mm . . . . . | | 20 | |
| Maximum thickness of metal being cut, (St.3), mm. | — | — | 3 |
| Maximum cutting rate, m/min . . . . . . . | — | — | 0,5–0,6 |
| Number of dual strokes of crosshead, min . . . . | | | 1600 |
| Air consumption at pressure of 5-6 kg/cm$^2$, m$^3$/hr | 1,3 | 1,4 | 0,8 |
| Weight, kg, at surface .. | 6 | 7,0 | 2,8 |
| Dimensions, mm . . . . . | | — | 288×152×378 |
| | — | 478 | — |
| | — | 130 | — |

Remark. The working pressure of the compressed air with an increase in submergence exceeding 10 m should be raised accordingly, figuring 1 atm per 10 m.

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## SPECIFICATIONS OF UNDERWATER ELECTRIC TOOL

| Parameter | Disk cutter | Electric drill | Small auxiliary electric drill |
|---|---|---|---|
| Diameter, mm, of cable being cut . . . . . | To 65 | — | — |
| Type of electric motor | Three-phase, 200 cps, underwater shortcircuited | | |
| Net power, watts . . . | 1800 | 1000 | 100 |
| Voltage, v. . . . . . . | 127 | 127 | 127 |
| Rotation speed of rotor, rpm . . . . | 11200 | 11600 | — |
| Rotation speed of shaft, rpm . . . . | 2000 | 340 | 1200 |
| Diameter of grinding wheel, mm . . . . | 175 | — | — |
| Thickness, mm . . . . | 2—2,5 | — | — |
| Maximum cutting depth, mm | 58 | — | — |
| Maximum drilling diameter . . . . . . | — | 25 | 6 |
| Dimensions, mm . . . | 480×400×90 | 295×515×220 | 30×70×130 |
| Weight at surface, kg. | 9 | 9,5 | 2 |
| Permissible depth of submergence, m . . . | The maximal for a diver in soft gear. | | |

Appendix 24

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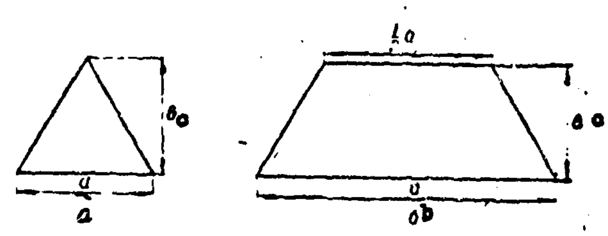
## RECOMMENDED SHAPES AND SIZES OF PATCHES
(covering sheets)



| Approximate dimensions of triangular patches, mm | | Perimeter, mm | Maximal diameter (mm) of hole being covered | Approximate dimensions of trapezoidal patches, mm | | Perimeter, mm | Maximal diameter (mm) of hole being covered |
|---|---|---|---|---|---|---|---|
| a | c | | | a | c | | |
| 300 | 260 | 900 | 120 | 500 | 216 | 1250 | 116 |
| 400 | 346 | 1200 | 180 | 600 | 260 | 1500 | [illegible] |
| 500 | 432 | 1500 | 240 | 700 | 302 | 1750 | 202 |
| 600 | 520 | 1800 | 300 | 800 | 346 | 2000 | 245 |
| 700 | 605 | 2100 | 360 | 900 | 388 | 2250 | [illegible] |
| 800 | 690 | 2100 | 410 | 1000 | 432 | 2500 | 322 |
| 900 | 780 | 2700 | 470 | 1100 | 475 | 2750 | 375 |
| 1000 | 865 | 3000 | 530 | 1200 | 520 | 3000 | 420 |
| 1100 | 950 | 3300 | 590 | 1300 | 563 | 3250 | 465 |
| 1200 | 1010 | 3600 | 650 | 1400 | 605 | 3500 | 505 |
| 1300 | 1130 | 3900 | 700 | 1500 | 650 | 3750 | [illegible] |
| 1400 | 1210 | 4200 | 760 | 1600 | 690 | 4000 | 540 |



Remarks: 1. In the cases when the hole is elongated in form, one should utilize patches (covering sheets) of a trapezoidal or other shape (e.g., rectangular) adjusted to the dimensions of the hole.

2. In the cases when the sizes of the hole exceed the dimensions of the steel sheets which are available, the patching of the hole is accomplished with a combined patch including an end lap.

3. We recommend that the patches' corners be rounded off.

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TECHNICAL SPECIFICATIONS OF TOOLS USED IN MECHANICAL CLEANING OF SURFACES PRIOR TO PAINTING THEM UNDER WATER

| Parameters | Cluster-type pneumatic hammer | Triple-headed pneumatic hammer | Pneumatic machine |
|---|---|---|---|
| Purpose | Removal of caked rust & old paint cavities & dents | Removal (knocking off) of solid rust, scale & old paint | Cleaning the metal surface |
| Type of engine | Rotor | Rotor | Rotor |
| Number of head impacts per minute | 1800 | 1800 | 600 rpm |
| Consumption of compressed air at pressure of 5 kg/cm² | 5–6 | 18–20 | 1,5 |
| Disk diameter, mm | — | — | 190 |
| Length of "brush", mm | — | — | 18 |
| Dimensions, mm | 220×44×190 | 122×76×418 | — |
| Weight, kg, at the surface | 2,0 | 2,5 | 6 |

Appendix 26

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TECHNICAL SPECIFICATIONS OF INSTALLATION FOR CENTRIFUGAL UNDER WATER AND ON A WET SURFACE

| Parameters | Painting machine | Balance beam | Paint-pumping tank | Heating unit | Water-oil separator |
|---|---|---|---|---|---|
| Purpose | Distribution & spreading of paint over the surface being painted | Support of painting machine during painting of ship sides & vertical surfaces | Providing a supply of paint to working disk of painting machine | Distillation of solvents from original lacquer (paint) | Water- and oil-cleaning of compressed air, entering the painting machine |
| Type or brand | — | Spring | Cylindrical | Electrical(cylindrical) | Twin-cylinder |
| Type of engine | Pneumatic rotor | — | — | — | — |
| Number of rpm: | | | | | |
| without load | 600 | — | — | — | — |
| with load | 350–475 | — | — | — | — |
| Output, hp/kw | 0,75 | — | — | 4 | — |
| Voltage, v. | — | — | — | 220 | — |
| Air pressure, kg/cm² | 5 | — | 5 | — | 5 |

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| Parameter | Painting machine | Balance beam | Paint-pumping tank | Heating unit | Water-oil separator |
|---|---|---|---|---|---|
| Air consumption (output), $m^3$/min . . . . . . . . | 1,5 | — | — | | 3,0 |
| Diameter of working disk, mm . . . . . . | 80 | — | — | | — |
| Load-lifting cap., kg | — | 5—10 | — | | |
| Range, m, of lifting height . . . . . . . | — | 2 | — | | |
| Capacity, liters . . . | — | — | 18 | 17 (tank) 12 (inter-jacket space) | |
| Time of heating lacquer (paint) in water bath to 95°C, hrs . . . . . | — | — | — | 0,7 | |
| Dimensions, mm . . . . . | 295×255×220 | 200×150×80 | 650×250 | 420×380 (without tank) 525×380 (with tank) | 437×162×320 |
| Weight (unloaded) on surface, kg . . . . | 6 | 3 | 17 | 18,5 | 7,5 |

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## TECHNICAL SPECIFICATIONS OF ETHYNOL PAINTS SUITABLE FOR APPLICATION UNDER WATER

| Parameter | Brand of paint | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EKZhS-40 | EKSS-50 | ELM-54 | EKKL-154 | EKKL-155 | EKBT-202 | EE-85 | EE-75 |
| Color . . . . . . . | Reddish-brown | Orange | | Black | Black | Black | | |
| Time of complete drying at 20°C, not more than (at surface), hours . . . . . | 10 | 10 | 25 | 0,75 | 0,25 | 3 | 24 | 24 |
| Viscosity of original lacquor, sec, according to* | 10 | 10 | | — | — | 18 | | |
| Flexibility, mm, not over. . | 5 | 5 | | 3 | 3 | 1 | 1 | 1 |
| Pendulum hardness, at least | 0,6 | 0,65 | 0,8 | — | — | 0,77 | 0,3 | 0,18 |
| Impact resistance, kgcm, not less than . . . . . | 30 | 15 | 50 | — | — | — | 10 | 10 |
| Water absorption, %, not over | 0,5 | 0,5 | | | | | | |
| Resistance to effect of sea water, days . . . . | 180 | 150 | — | 500 | >500 | — | — | — |
| Consumption of paint (approximately), g/$m^2$. . | 110 | 125 | — | — | — | — | — | — |

* VZ-4 viscosimeter

Remark. The data were excerpted from Ye.V. Iskra's book Etinolevyye Kraski (Ethynol Paints), Sudpromgiz, 1960.

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## COMPOSITION OF ETHYNOL PAINTS SUITABLE FOR UNDERWATER APPLICATION (in %)

| Parameter | Brand of paint | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EKZS-40 | EKSS-50 | EIL-54 | EKKL-158 | EKKLO 155 | EKEP-202 | EE-85 | EE-75 |
| Lacquer, ethynol . . | 60-65 | 50-45 | 25 | 75 | 90 | 50 | 85 | 75 |
| Dry ferrous red lead. | 40 35 | — | — | — | — | — | — | — |
| Red lead . . . . . . | — | 50-55 | — | — | — | — | — | — |
| Lacquer, epoxyd ED6 | — | — | — | — | — | — | 15 | 25 |
| Lacquer, 411. . . . . | — | — | — | — | — | 50 | — | — |
| Coal-tar lacquer . . | — | — | — | 25 | 10 | — | — | — |
| Rosin ether . . . . | — | — | 25 | — | — | — | — | — |
| Chlorinated fatty acids of paraffin . . | — | — | 25 | — | — | — | — | — |
| Turpentine . . . . . | — | — | 25 | — | — | — | — | — |

Remarks. 1. The percentual content of the paints is given, proceeding from the requirements of application to a dry surface in air.

2. During utilization under water, the ethynol paints are concentrated in accordance with the conditions of application.

3. Ethynol lacquer (divinylacetylene) is produced in conformity with VTU-1267-54, while the coal-tar lacquer's production conforms with GOST 1709-60.

4. See Remark under Appendix 27, above.

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